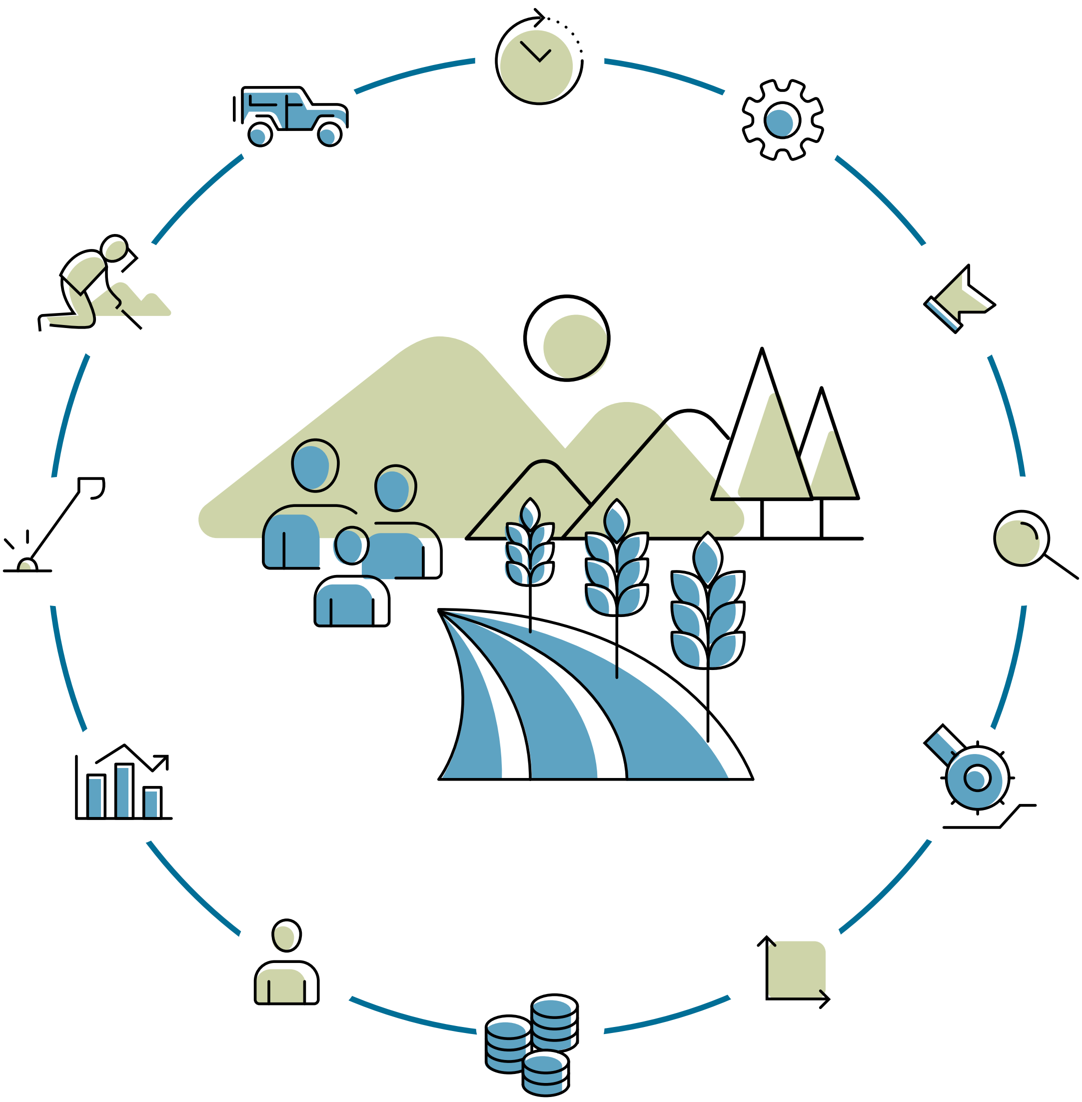


OPERATIONAL EFFICIENCY IN MINE ACTION

ANNEXES

MARCH 2023

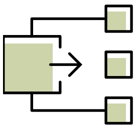
ANNEXES - TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

ADS	Animal Detection System
AP	Anti-Personnel
ARE	All Reasonable Effort
AV	Anti-Vehicle
BAC	Battlefield Area Clearance
BiH	Bosnia and Herzegovina
CHA	Confirmed Hazardous Area
CM	Cluster Munition
CMR	Cluster Munition Remnant
CROMAC	Croatian Mine Action Center
DMAC	Directorate of Mine Action Coordination (Afghanistan)
EO	Explosive Ordnance
ERW	Explosive remnants of war
ILO	International Labour Organization
IMAS	International Mine Action Standards
IMSMA	Information Management System for Mine Action
KPI	Key Performance Indicator
LMAC	Lebanon Mine Action Centre
MAO	Mine Action Organisation
MASG	Mine Action Support Group
NMAA	National Mine Action Authority
NMAS	National Mine Action Standards
NTS	Non-Technical Survey
OECD	The Organisation for Economic Co-operation and Development
SHA	Suspected Hazardous Area
TS	Technical survey
UXO	Unexploded Ordnance

ANNEX A - DETAILED FINDINGS

Outputs/production

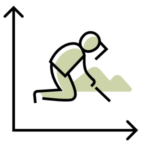


Production represents the output of the land release process[1]. It is not just a passive indicator of deliverables but is influenced by decisions taken by land release planners and managers. The extent to which these decisions are valid and 'efficient' has a direct impact on the success of a land release project or programme.

The process of identifying a suspected hazardous area (SHA) and refining its extent, through non-technical survey (NTS) and technical survey (TS), to establish a confirmed hazardous area (CHA), results in a lower level of 'production' needed to confidently declare land as safe for release. A lower production figure (P) means fewer resources (N) and less time (T) needed to achieve the objective. Accurately defining the area requirement results in quicker task completion and frees up resources for other tasks, increasing the benefits to affected countries and territories.

For this study, the primary operational output is the number of square metres of land accepted and handed over for release. Landmines, cluster munition remnants (CMR) and other unexploded ordnance (UXO) are a by-product of the land release process. These by-products help to assess the effectiveness of land release decisions, including identifying suspected and confirmed hazardous areas, and releasing land through cancellation, reduction and clearance.[2]

Square metres of land per item of explosive ordnance found



This study uses the definition of explosive ordnance (EO) found in IMAS 04.10.[3] It includes mines, cluster munitions, unexploded ordnance, abandoned explosive ordnance, booby traps, other devices defined by the Convention on Certain Conventional Weapons Amended Protocol II,[4] and improvised explosive devices. Data providers for the study were asked to report on all EO found during field operations, excluding ammunition of less than 20 mm calibre. Data was disaggregated by landmine and CMR where possible.

The area released or cleared per EO item found is primarily influenced by two factors: how easy or difficult it is to define the extent of EO contamination; and how successfully land release decision makers establish that definition. A lower ratio indicates a more targeted land release effort. A lack of information leads to uncertainty and, by extension, increased risk.[5] Decisions regarding which land to release and when to do it safely demonstrate the practical effects of risk and uncertainty. In cases where mine action decision makers have limited information, or do not consider that information fully reliable, they are more likely to extend clearance operations.

[1] The focus of this study is on the production of safe land for follow-on use, but it is fully understood that the land release process has other 'products', the most significant of which is information via records and reports.

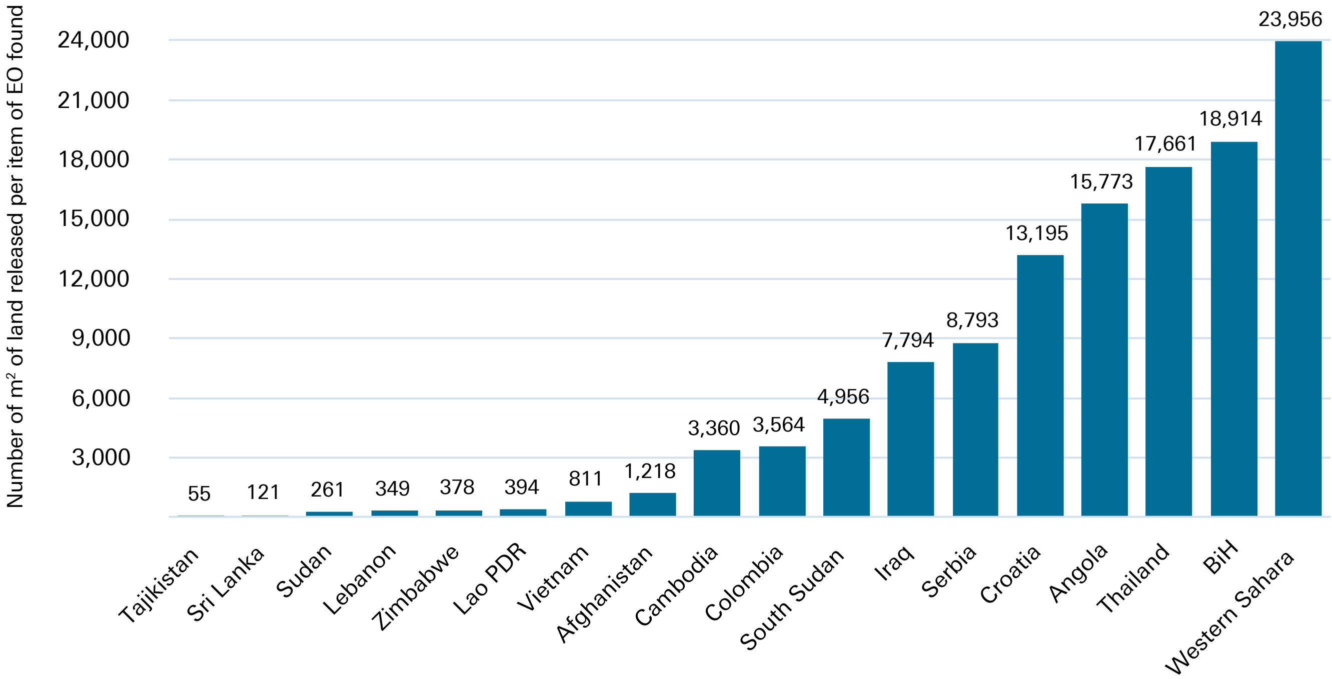
[2] In other mine action processes, such as stockpile destruction, destroyed or demilitarised EO items would be the primary product.

[3] IMAS 04.10: Glossary of mine action terms, definitions and abbreviations (second edition, January 2003; amendment 10, February 2019), definition 3.99.

[4] Convention on Certain Conventional Weapons (CCW), Amended Protocol II.

[5] Risk is defined as "the effect of uncertainty on objectives" in IMAS 07.14: Risk Management in Mine Action (first edition, February 2019), Section 3: Terms, definitions and abbreviations.

Figure 1: Average number of square metres of land released per item of explosive ordnance found.



Note: NMAA data was provided for ten countries and open-source information was used for eight countries.

Square metres of land released per item of explosive ordnance found

Figure 1 shows the aggregated and annualised average number of square metres of land released per item of explosive ordnance found between 2015 and 2019, for each of the countries and territories that provided data for this study. The data comes from a combination of responses received from National Mine Action Authorities (NMAAs) and open-source data (primarily the Landmine and Cluster Munition Monitor) for countries where no NMAA data was available.[6]

The highest value (Western Sahara, 23,956 m^2) is almost 440 times higher than the lowest one (Tajikistan, 55 m^2).[7] Like most aspects of mine action, many factors influence this key performance indicator (KPI). While it can be difficult to distinguish the influence of each factor, it is possible to identify circumstances in different countries that may account for this wide range of results.

Territories with densely mined areas, notably those possessing minelaying records (for example, Lebanon and Zimbabwe), and territories which have been subject to intensive cluster munition or bombing campaigns (for example, the Lao PDR) are associated with lower KPI values.

Typically, longer established programmes, such as those in Bosnia and Herzegovina and Angola, have already cleared the most densely contaminated areas, and are now focussing on areas that are much harder to define, including 'nuisance mining' areas. In some countries, such as Angola, resurvey programmes during the period of this study resulted in the release of extensive areas through cancellation and without further technical intervention.[8]

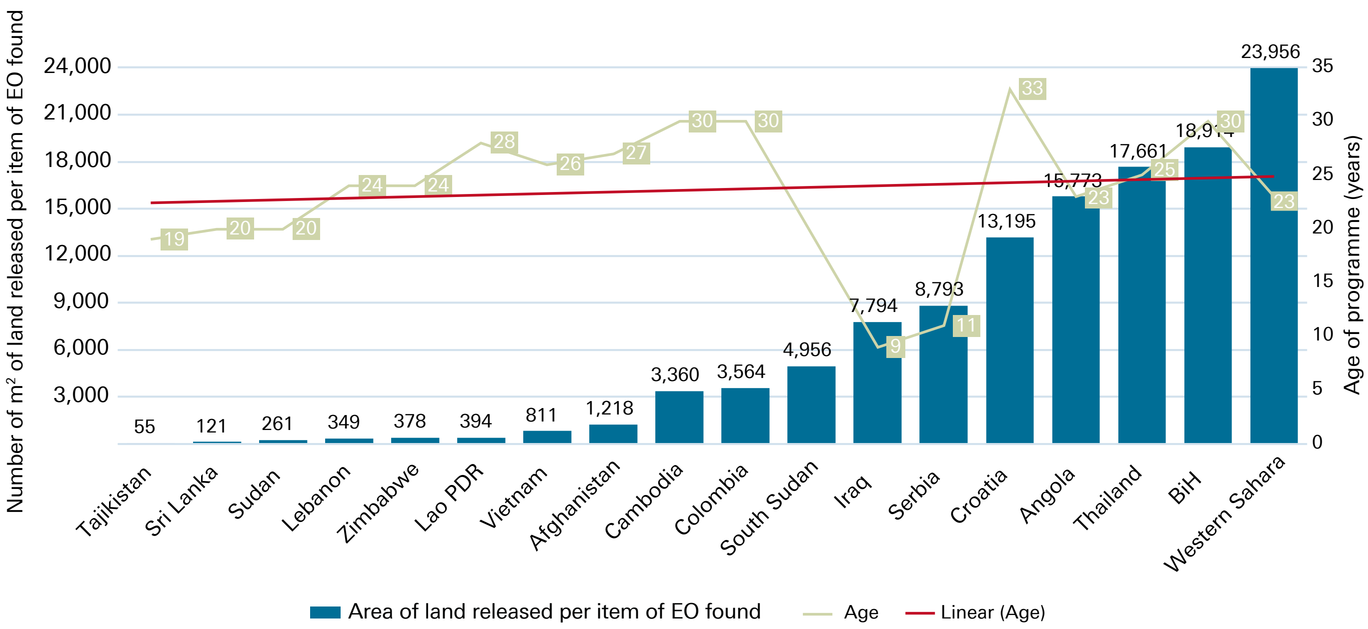
The complexity of the factors associated with mine action means that strong direct correlations with individual factors are scarce. Figure 2 shows that, while the age of the programme may have some influence on the area released per item of EO found, there is no clear overall relationship. Countries like Bosnia and Herzegovina and Angola, which engaged in substantial resurvey programmes during the period covered by this study (2015–2019), are likely to have particularly high numbers of square metres of land released per item of EO found.

[6] Landmine and Cluster Munition Monitor, "Homepage", accessed 6 April 2023, http://www.the-monitor.org/en-gb/home.aspx.

[7] Annex B discusses factors influencing this KPI in more detail.

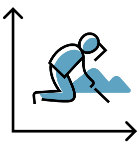
[8] A Landmine and Cluster Munition Monitor, "2019 Country profile for Angola", accessed 6 April 2023, http://www.the-monitor.org/en-gb/reports/2019/angola/mine-action.aspx#ftnref1.

Figure 2: Average number of square metres of released land per explosive ordnance item found, in comparison to the age of the national programme in years.



Note: The start date in the Landmine and Cluster Munition Monitor country reports 2021 was used.

Square metres of land cleared per item of explosive ordnance found



The analysis of the area of land cleared per item of EO found gives a similar range of results, though at a lower level. This reflects the usual expectation that the area of cleared land is likely to be smaller than the area of land released. Figure 3 shows the number of square metres of land cleared per item of explosive ordnance found. In this case, the highest value (Croatia, 10,897 m^2) is about 545 times higher than the lowest one (Tajikistan, 20 m^2).

Differences between areas of land released and cleared per item of EO found provide an indication of the overall ratio of land cleared to land released discussed below.

For example, in Angola, the area of land cleared is 40.9 times larger than the area of land released, reflecting the impact of widespread cancellation following resurvey. The comparatively small area of land released (385 m^2) indicates that, in areas that remained defined as suspected or confirmed hazardous areas following resurvey, operations targeted a higher level of land release than the global average.

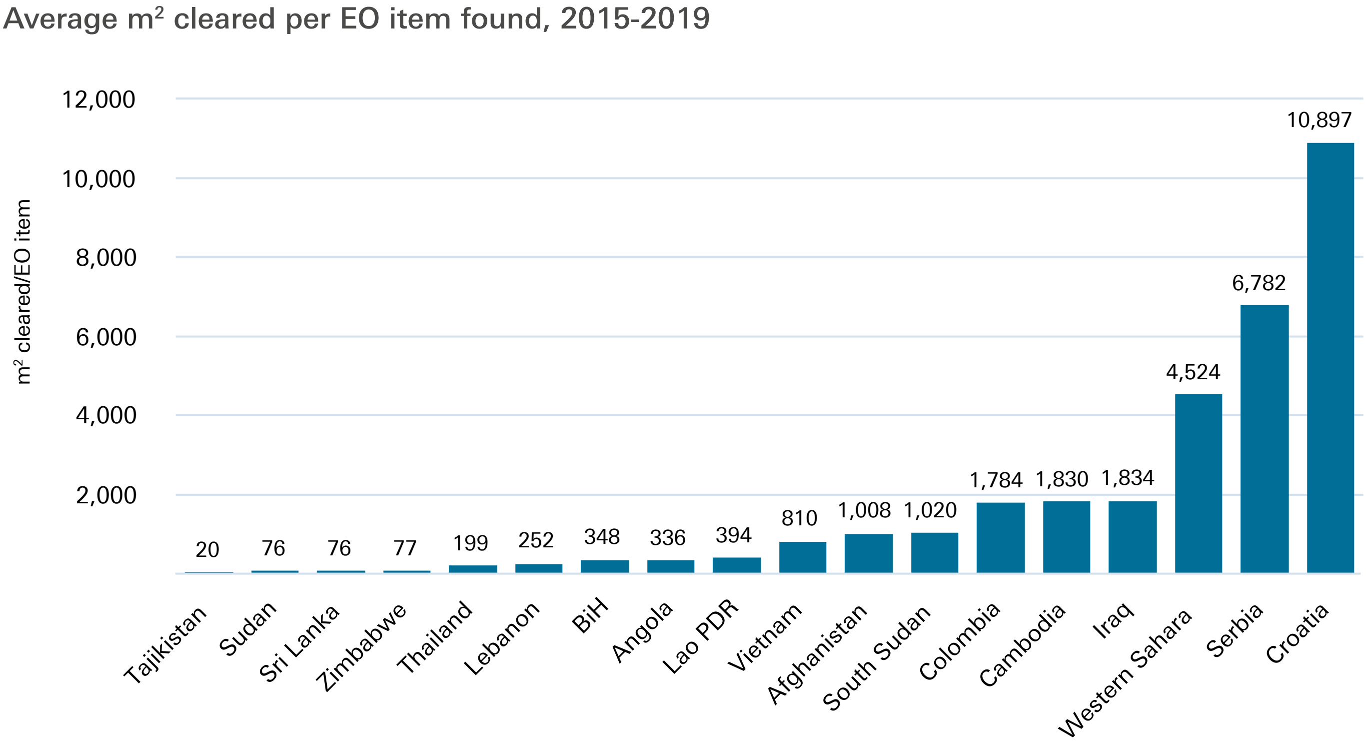
The figures for clearance reflect the possibility to target activity more efficiently in directly contaminated areas. The area of land cleared per EO item found is heavily influenced by the type of contamination present. Barrier minefields typically offer the best opportunities for targeted clearance activities. As a result, countries such as Zimbabwe, which have this type of mine contamination, have lower rates of land cleared compared to other countries.

Operations conducted soon after cluster munition (CM) strikes can also provide evidence to support effective and confident land release decision-making[9] On the other hand, battlefield area clearance (BAC) work in former conflict areas or where historic CM strikes have left little evidence, such as Vietnam and the Lao PDR, are associated with larger areas of land cleared per EO item found. This is in contrast to countries where evidence is more readily available, such as some parts of Lebanon, and areas where conflict is ongoing or recent, such as Ukraine.

The KPI is also affected by the local land release policies and procedures, and the confidence of local authorities in making land release decisions.

[9] As was the case in Kosovo when CMR clearance operations started immediately after the NATO bombing campaign in 1999 and can be expected in Ukraine during current CMR clearance operations.

Figure 3: Average number of square metres of land cleared per item of explosive ordnance found.



Note: NMAA data was provided for ten countries and open-source information was used for eight countries. The average area of land cleared per item of explosive ordnance found across the countries of this study is 1,795 m².

The study aimed to determine if a correlation existed between the understanding and acceptance of all reasonable effort (ARE) and liability, and the extent of clearance operations.[10] Mine action organisations were asked: *'to what extent is "liability" in relation to released land [...] defined and applied' and 'to what extent is "all reasonable effort" defined in national standards and applied in practice'.*

The notion of ARE is closely linked to the concept of operational efficiency. ARE in its definition "describes what is considered a minimum acceptable level of effort to identify and document contaminated areas or to remove the presence or suspicion of explosive ordnance".[11] Many of the KPIs in this study measure the application of all reasonable effort. One of the guiding principles of ARE is to establish policies that clarify how the liability of land release is to be assigned.

One issue in the land release process is the assignment of liability for explosive hazards found in released areas. In programmes with unclear liability policies, there is hesitation to clear land without the full land release process, which can be inefficient. Liability is increasingly important in mine action as land release methodology and procedures have become more formalised, and this has a direct impact on the efficiency of operations.

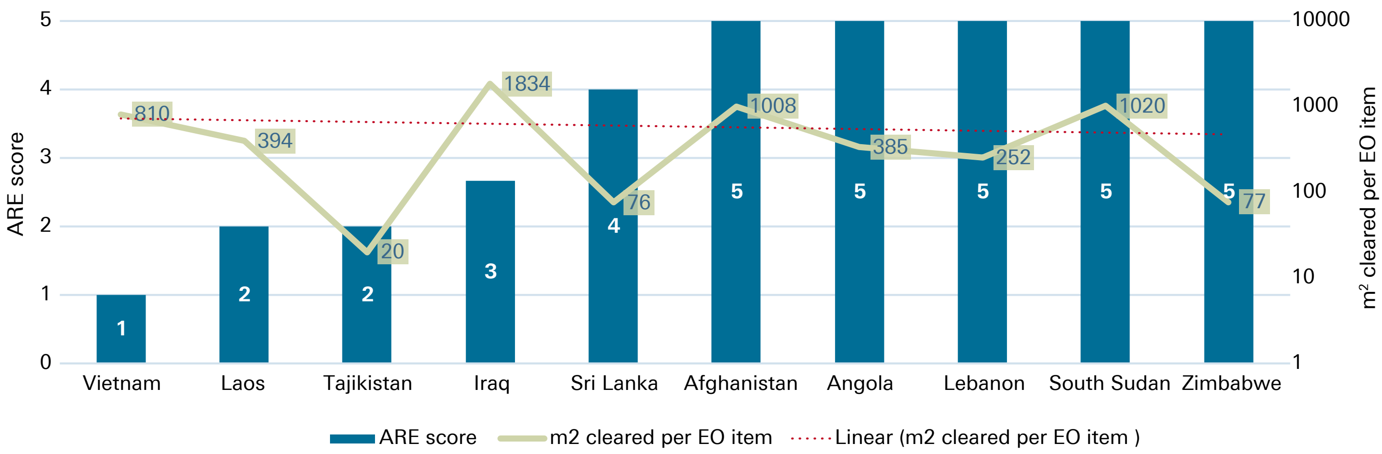
For the question on the perception of ARE, the 39 responses received from various operators across the world break down as follows:

- Not defined – 7
- Insufficiently defined – 4
- Somehow defined but not applied – 7
- Well defined but not applied – 16
- Well defined and applied – 5

[10] The concept of ARE is described in detail in TNMA 07.11/03: All Reasonable Effort.

[11] Refer to IMAS 04.10: Glossary of mine action terms, definitions, and abbreviations, definition 3.10 – all reasonable effort.

Figure 4: Perception of how well-defined all reasonable effort is in comparison to the number of square metres of land cleared per item of explosive ordnance found (plotted on a logarithmic scale).



Well-defined and applied = 5; Well-defined but not applied = 4; Somehow defined but not applied = 3; Insufficiently defined = 2; Not defined = 1

Note: ARE data from responses of a total of 23 mine action organisation across 10 countries.

For the question on liability, the 39 responses break down as follows:

- Not defined – 7
- Insufficiently defined – 6
- Somehow defined but not applied – 8
- Well defined but not applied – 13
- Well defined and applied – 5

While it is reasonable to expect a correlation between the perception of ARE and liability, and the efficiency of clearance operations, the study found no compelling evidence of this. However, this should not be taken as a definitive result as the data set for the perception of ARE and liability is arguably small, averaging just over two mine action organisation (MAO) responses per country across 10 countries. Furthermore, despite these results, there is evidence that uncertainty about ARE and liability, theoretically and in practice, remains one of the topics for which support is most requested by NMAAs and MAOs.[12]

Figure 5 offers another perspective by comparing the number of landmines found and the area of land cleared per landmine found in Cambodia and Lebanon. The full data set chart is provided in Annex A. The trend lines for the two countries are shown along with the associated global trend line, but the individual data points have been hidden for greater clarity. Only sites where at least 75% of all explosive ordnance were landmines were included in this analysis.

The graph shows clearly that the greater the number of mines found at a site, the smaller the area cleared per item. Indeed, sites with a large number of mines are typically associated with pattern or barrier minefields, making it easier for land release decision makers to confidently apply ARE and avoid clearing areas that do not contain mines.

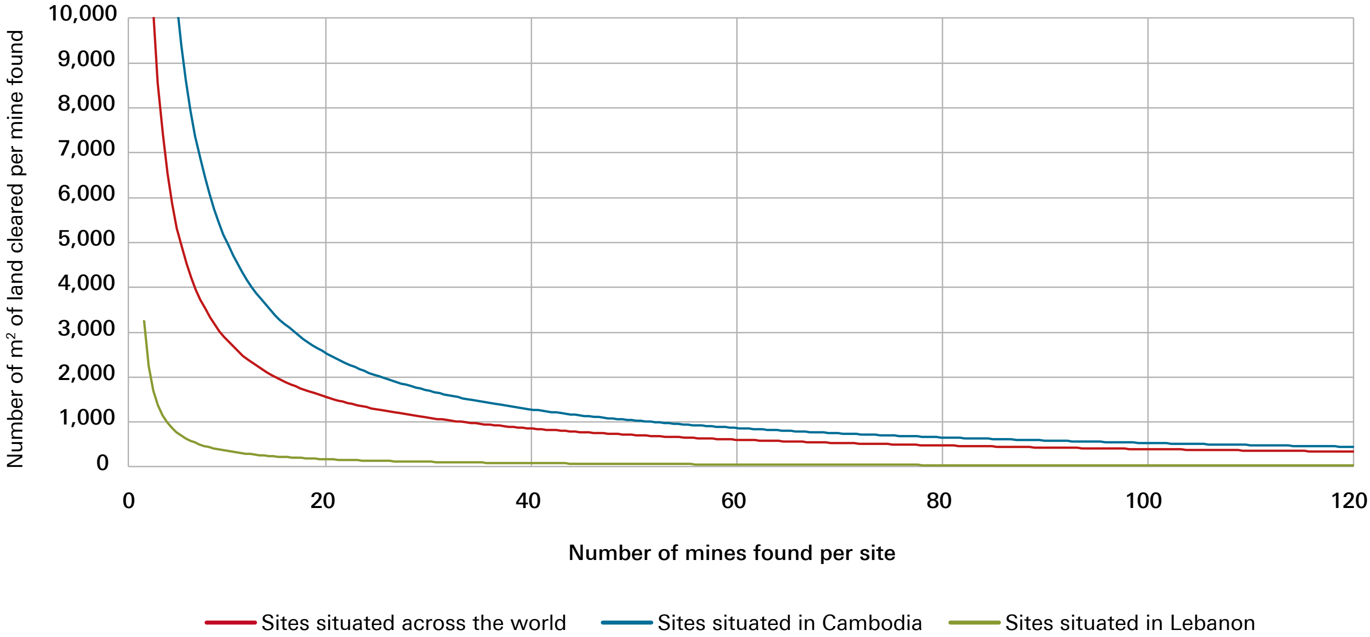
In contrast, mines are likely to be widely dispersed at sites where there are few of them. This makes clearance more difficult, requires additional technical survey and involves fade-out clearance of a much larger area around each mine.

It is important to note, however, that each country or site would need to be studied individually in order to understand the particular dynamics between the different influencing factors. For example, incorrect NTS/TS to define contamination could result in large hazardous areas requiring a significant amount of work.

As shown in Figure 5, when the number of mines found at a site becomes relatively large (over 100), the results in individual countries as well and globally converge, while there are marked differences with lower numbers of mines. A similar trend can be expected for larger minefields in any other territory.

[12] Based on topics for which the GICHD is asked to provide support.

Figure 5: Number of square metres of land cleared per mine found (anti-personnel and/or anti-vehicle).

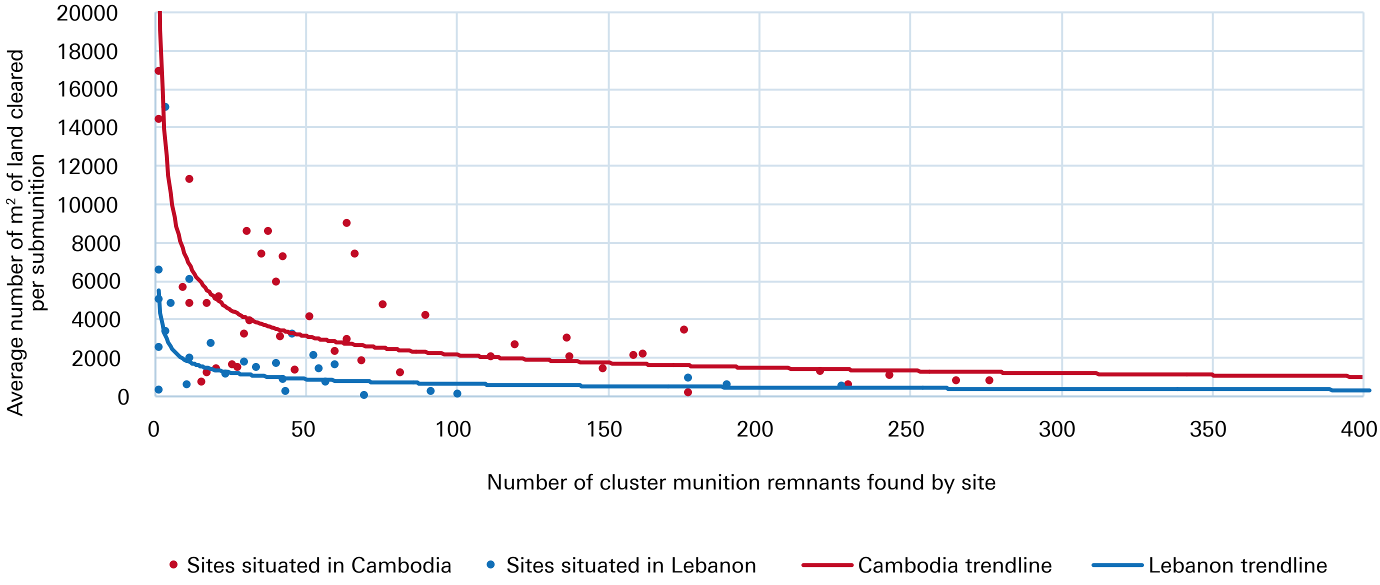


Note: Trend lines for global results (2,286 sites), for Cambodia (439 sites) and Lebanon (74 sites). Only sites where at least 75% of the total explosive ordnance count in MAO data was landmines were included.

In Lebanon, many sites containing mines tend to be in well-defined, often recorded and marked patterns. The high level of confidence in the available information supports efficient decision-making, which is reflected in the rapid drop-off in the Lebanon trend line. However, the situation is different in Cambodia, where barrier minefields (primarily in the K5 belt) exist, but the level of predictability is lower and similar documentation is unavailable. Due to the frequent battles over military bases by the Khmer Rouge and the Vietnamese, mines were re-laid several times, leading to inconsistent mine-laying patterns. As local informants are ageing or have moved away since the war, conducting NTS is increasingly challenging in Cambodia. In addition, new migrants who have occupied the land for a short time often lack historical knowledge of mine-laying patterns in that area, creating unique issues for land-release decision makers.

The distribution of mines has a significant effect on the area of land cleared per mine found. Even minor changes in the average distance between mines can greatly influence the total area of land cleared per mine found. For example, doubling the average distance between mines in a pattern can quadruple the area containing that pattern. Similarly, small changes to fade-out or buffer zone distances can result in much larger proportional increases to the total area of land cleared.

Figure 6: Average number of square metres of land cleared per cluster munition remnant found.



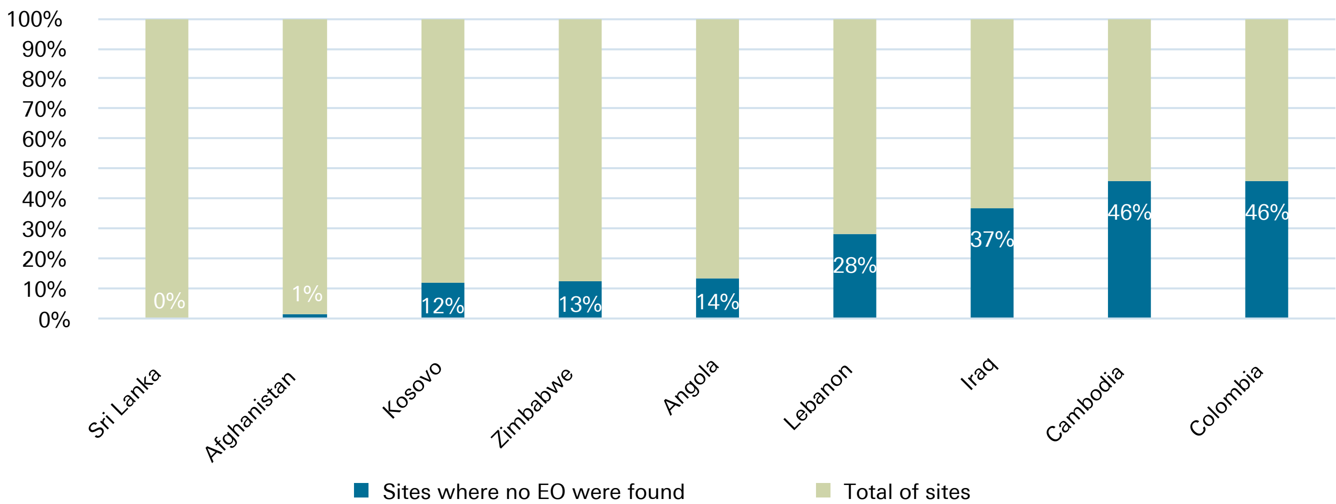
Note: MAO site data for 50 sites in Cambodia and 30 sites in Lebanon.

Figure 6 extends the analysis to 80 CMR sites in Cambodia and Lebanon. Once again, the relationship between a higher number of CMRs at a site and a lower area of land cleared per CMR found is apparent. The average area of land cleared per CMR found is generally lower for Lebanon than Cambodia, and the variations around the trend line are not as significant.

Individual site dots for Lebanon are close to the trend line, while some of them are significantly higher than the trend line for Cambodia, suggesting different contexts at CMR sites in the two countries. Whereas the CMR contamination in Lebanon is characterised as dense, it is relatively recent (1990s/2000s) compared to Cambodia (1970s), where residents have already removed some of the CMR on their land. This may explain why operators find fewer items for a larger area of land cleared. Moreover, the shorter time elapsed since contamination makes access to local knowledge easier in Lebanon than in Cambodia, thus facilitating land release decision-making.

Releasing an area of land through clearance without discovering any explosive ordnance is undesirable in terms of efficient deployment of technical resources. While there may be arguments to justify such action, it remains that applying expensive clearance assets to land that contains no explosive ordnance threat indicates some deficiency in information management and/or decision-making. The study received data on a total of 10,122 separate task sites. Clearance was the dominant release methodology in at least 4,000 of them (identified as sites where 75% or more of the total land released was cleared). Of these sites, 26% reported no explosive ordnance found.

Figure 7: Percentage of sites by country where no explosive ordnance items were found.

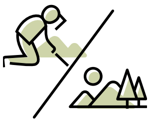


Note: Extracted from MAO site data. A total of 3,692 sites met the inclusion criteria.

Figure 7 shows the percentage of zero explosive ordnance clearance tasks in countries where more than 10 sites met the inclusion criteria. A strong variation among countries is visible (between 0% and 46%). At the top end are Cambodia and Colombia, where contamination is scattered and the mine threat not always clearly defined. At the lower end are Sri Lanka and Afghanistan, where a combination of experience and information availability help explain the very low zero-explosive ordnance rate, as well as the greater likelihood of non-mine explosive ordnance in many areas.

The Anti-Personnel Mine Ban Convention and the Convention on Cluster Munitions both require that each State Party undertake to identify all contaminated areas and ensure the destruction of cluster munition (CM) and anti-personnel (AP) mines located in contaminated areas under its control. While including all potentially contaminated areas may seem legitimate, it can lead to an excessive number of SHAs in initial surveys. Subsequent surveys may consequently cancel some of the excess area, but the possibility remains that more land is cleared than strictly necessary, leading to higher numbers of square metres of land cleared per explosive ordnance found.

Ratio of land cleared to land released



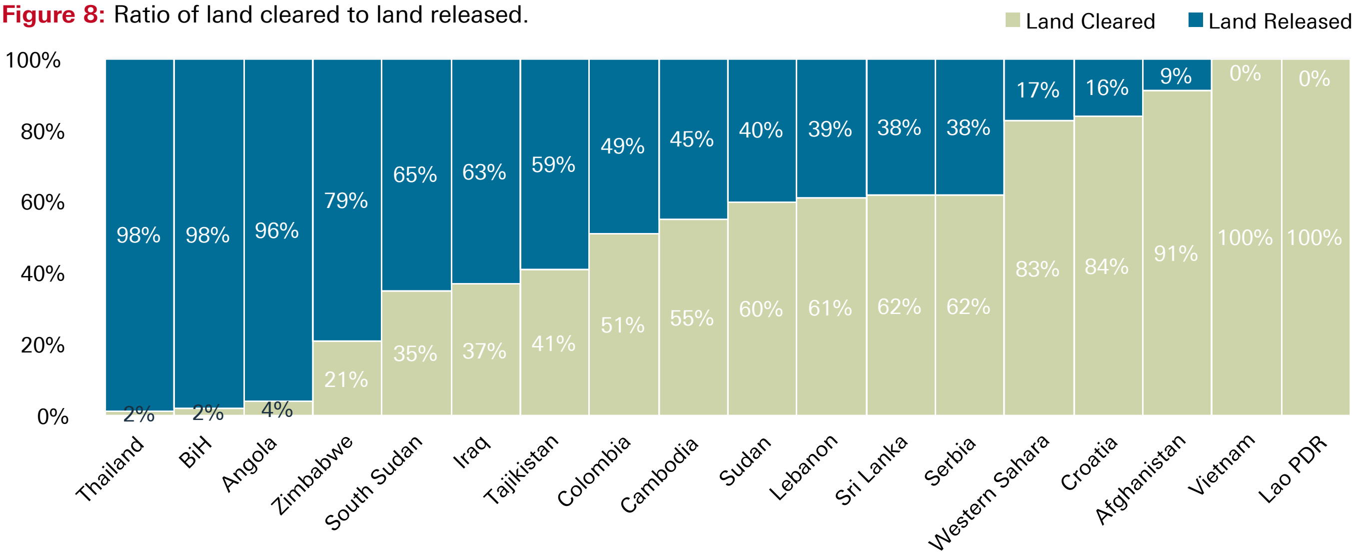
Land release decision-making is reflected in the ratio of land cleared to land released. Figure 8 shows results from the countries that provided data for the study. The results range from almost all land released being subject to clearance (Vietnam, Lao PDR) to only a small portion (Thailand, Bosnia and Herzegovina, Angola) with the remainder being cancelled or reduced.

The indicator is influenced by both current and historical decisions. Higher clearance rates are observed in territories where land-users drive much of the clearance effort, such as Vietnam, reflecting the desire of subsequent land users to ensure that all areas are cleared of unexploded ordnance.[13] Yet, the use of additional TS methods and the increased availability and analysis of operational data are expected to improve the confidence in land release decision-making, leading to a reduction in the proportion of land requiring clearance.

The ratio of land cleared to land released is also affected by legacy SHA definitions created during early survey initiatives, which tend to include larger areas of land than strictly necessary. Updated reviews or resurvey efforts can lead to the release of very large areas through cancellation.

A landmine impact survey was conducted in Angola in 2005. An updated NTS programme was completed in the lead up to the country's 2017 extension request and covering the period of operations for which data was captured in this study. It was reported that up to 90% of some areas were removed from the NMAA's database.[14] Thailand also reported high levels of release by cancellation as large SHAs were revisited, and their historical boundaries brought into more realistic polygons.[15] Ratios between 20% and 80% are associated with the majority of national programmes that experience a mixture of contamination types and that adopt land release approaches broadly, in line with International Mine Action Standards (IMAS) guidance.

Figure 8: Ratio of land cleared to land released.

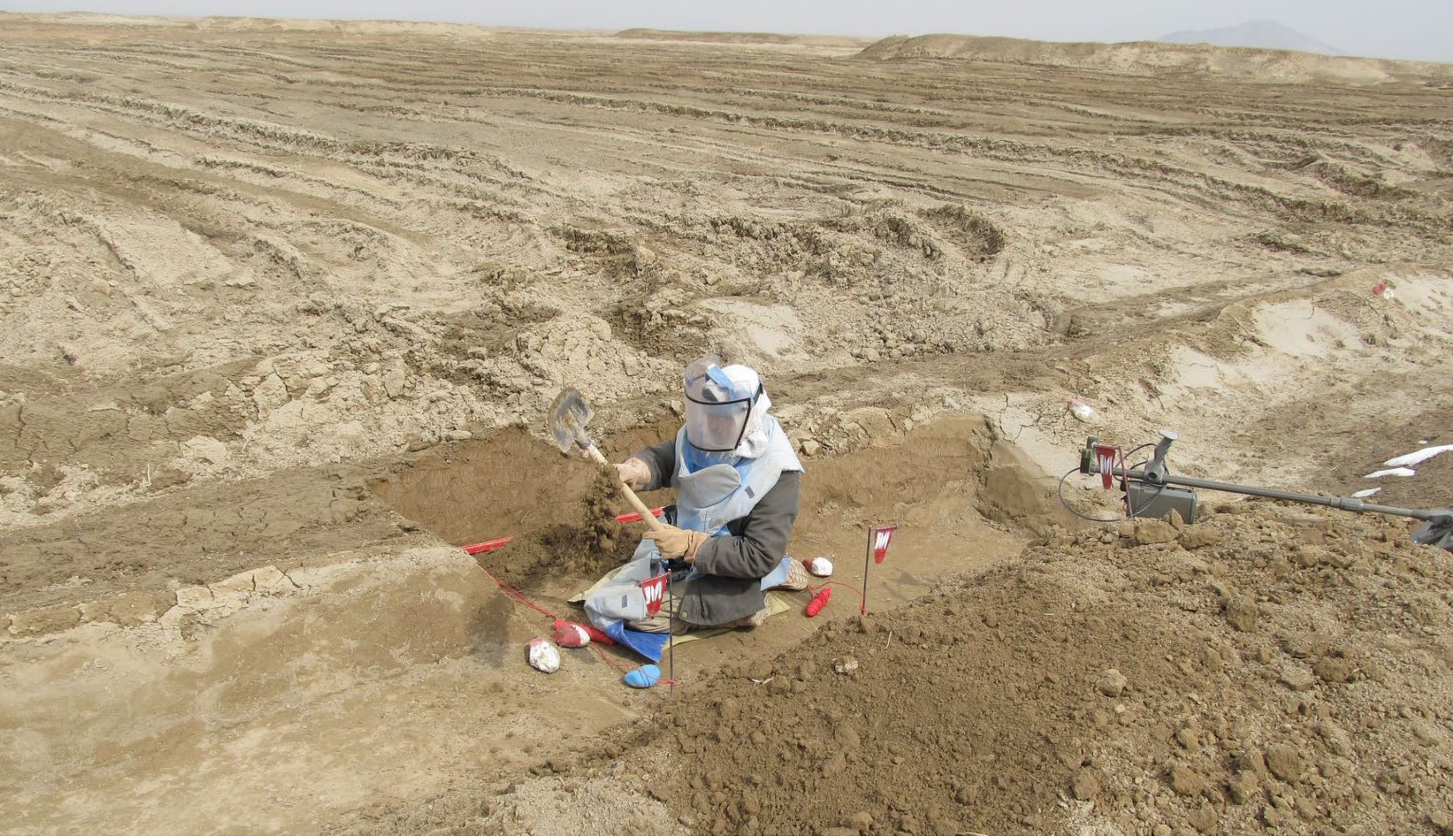


Note: NMAA data for nine countries, open-source data for ten countries and UN Office for Project Services data for one country.

[13] Many tasks are defined by the land user, who intends to build bridges, roads or other infrastructure. The threat is often a general unexploded ordnance one, rather than a mine threat. Opportunities for release of land through reduction are limited. The entire defined area is subject to clearance.

[14] Angola Mine Ban Treaty Article 7 Report for Calendar Year 2020, Transparency Report Angola April 2020 (apminebanconvention.org).

[15] Thailand Mine Ban Treaty Article 7 Report for Calendar Year 2017.


A deminer conducting clearance at an AV minefield. *Photo credit © GICHD.*

CASE STUDY

Case study – Ratio of land cleared to land released and the issue of anti-vehicle mines in Afghanistan

In 2019, a study by the GICHD found that 90% of land in Afghanistan was being released through clearance. A further analysis of data from 872 land released tasks completed in 2018–2019 showed that only 3% of land was cleared as a result of technical survey and 9% of areas were cancelled.

One of the challenges in effectively releasing land in Afghanistan is the type of contamination. In 2020, the GICHD conducted a follow-up study at the request of the Directorate of Mine Action Coordination (DMAC) to understand the impact of anti-vehicle (AV) minefields on the land release programme.

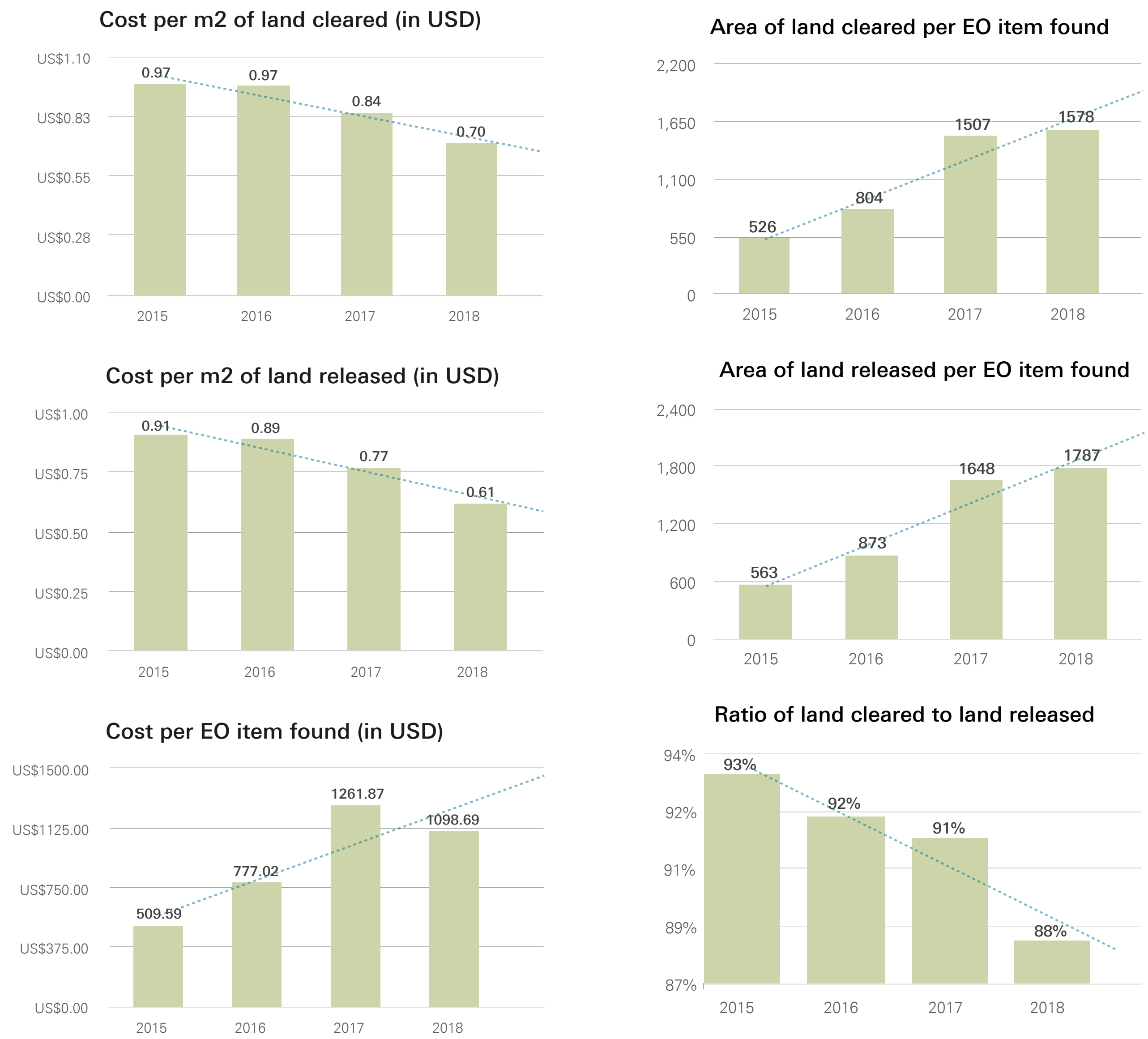
As of early 2020, over 65% of the remaining contamination in Afghanistan was from AV mines. These mines were historically laid in low densities by the mujahedin to disrupt tank movement over large flat areas. Due to the nature of the contamination, these areas posed a significant challenge for the efficiency of NTS. As a result, large areas were being cleared at great expense to uncover small numbers of AV mines. In 2019 alone, 30 hazardous areas larger than 1 square kilometre were cleared but no mines were found. Each anti-personnel (AP) mine removed in Afghanistan between 2009 and 2019 resulted in an average clearance of 2,702 square metres of hazardous area. However, for each AV mine, an average of 71,679 square metres of land was cleared. In other words, 27 times more land was cleared per AV mine found than per AP mine.

An additional analysis of progress reporting of AV hazards from 2017 to 2019 showed that a total of 251 hazardous areas has been worked on. The analysis revealed that:

- No mines were found in 49 hazardous areas (19.5%);
- An average of 2.32 AV mines were found per task;
- 116 tasks (46%) of hazards had only 1 or 2 AV mines;
- On average, more area was cleared on tasks with 1 or 2 AV mines (76,776 m^2) than on tasks with more than 2 mines (60,899 m^2).

This suggests that despite the significant effort and resources required to clear AV mines, they are often found in low numbers, and clearing a larger area does not necessarily result in a greater number of AV mines found.

Figure 9: KPIs in Afghanistan by year (2015–2018).



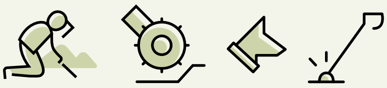
Note: Data provided by the national authorities in 2019. The data for 2019 is not included because the full year's data was not available at the time of data collection.

Table 1: Summary of land release KPIs for Afghanistan from 2009 to 2019.

Years	Total area of land cleared (in m²)	AP mines found	AV mines found	Area of land cleared per AP mine found (in m²)	Area of land cleared per AV mine found (in m²)	Ratio of area of land cleared per AP mine to area of land cleared per AV mine
2009	52 291 192	52 109	791	1 003	66 108	66
2010	67 720 162	33 739	1 089	2 007	62 186	31
2011	68 944 439	24 502	1 088	2 814	63 368	23
2012	77 171 813	24 308	2 012	3 175	38 356	12
2013	68 905 927	20 974	977	3 285	70 528	21
2014	42 801 960	12 684	523	3 374	81 839	24
2015	40 161 808	7 187	578	5 588	69 484	12
2016	48 532 624	14 055	446	3 453	108 818	32
2017	40 539 194	14 543	282	2 788	143 756	52
2018	46 717 920	8 943	263	5 224	177 635	34
2019	43 015 550	7 799	277	5 516	155 291	28
Grand total	596 802 589	220 843	8 326	2 702	71 679	27

Note: The data about areas cleared per AP and AV mine found was provided by the DMAC in February 2020.

Number of resources



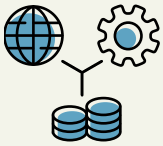
The analysis of the number of resources deployed for land release operations focuses on two management aspects:

- The proportion of deployed resources categorised as ‘productive’ (that is, who have the ability to release land) as opposed to those categorised as ‘enabling’ functions, such as medical or logistical support, and supervision;

- The proportion of productive resources that are actually engaged in productive activity at any time.

The analysis can be applied to any site but doing so requires access to detailed daily operational data. The analysis can be extended to include the deployment of animal detection systems (ADS) and mechanical systems. For the purposes of this section of the study, data was collected from manual clearance sites investigated in detail during case study deployments to Cambodia and Lebanon.

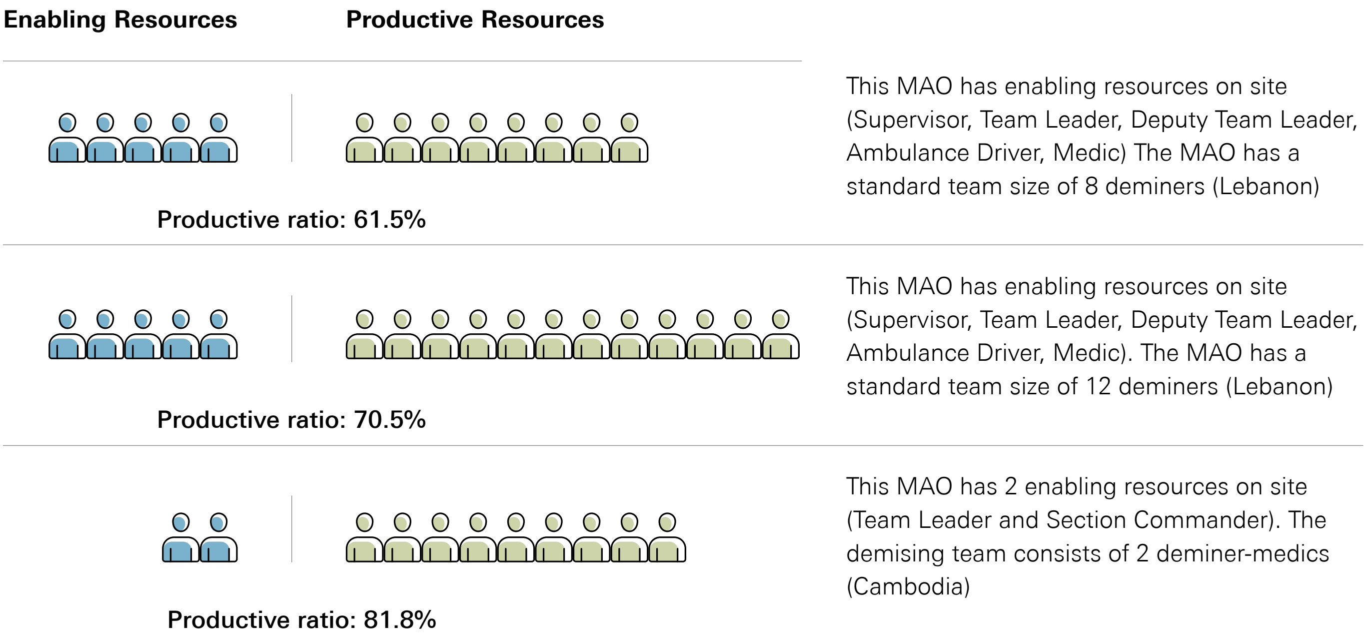
Productive resource ratios



The analysis of productive resources examines the proportion of resources available on site that are capable of delivering output, in this case land release. Typically, deminers are considered as productive resources. Although ADS and some mechanical systems can deliver output independently, they usually support and accelerate the progress of human deminers. Enabling resources are necessary on site to allow safe and reliable productive operations, such as supervisors, medical and logistical support, but they do not generate output by themselves. While non-productive enabling resources perform useful functions, they are not productive in terms of operational efficiency.

The different management policies adopted by MAOs have a significant impact on productive ratios. Figure 10 uses examples of different approaches adopted by MAOs working in Cambodia and Lebanon. It is important to note that neither of these two countries has a single common approach to team management, and individual MAOs have the freedom to adopt the approaches they prefer.

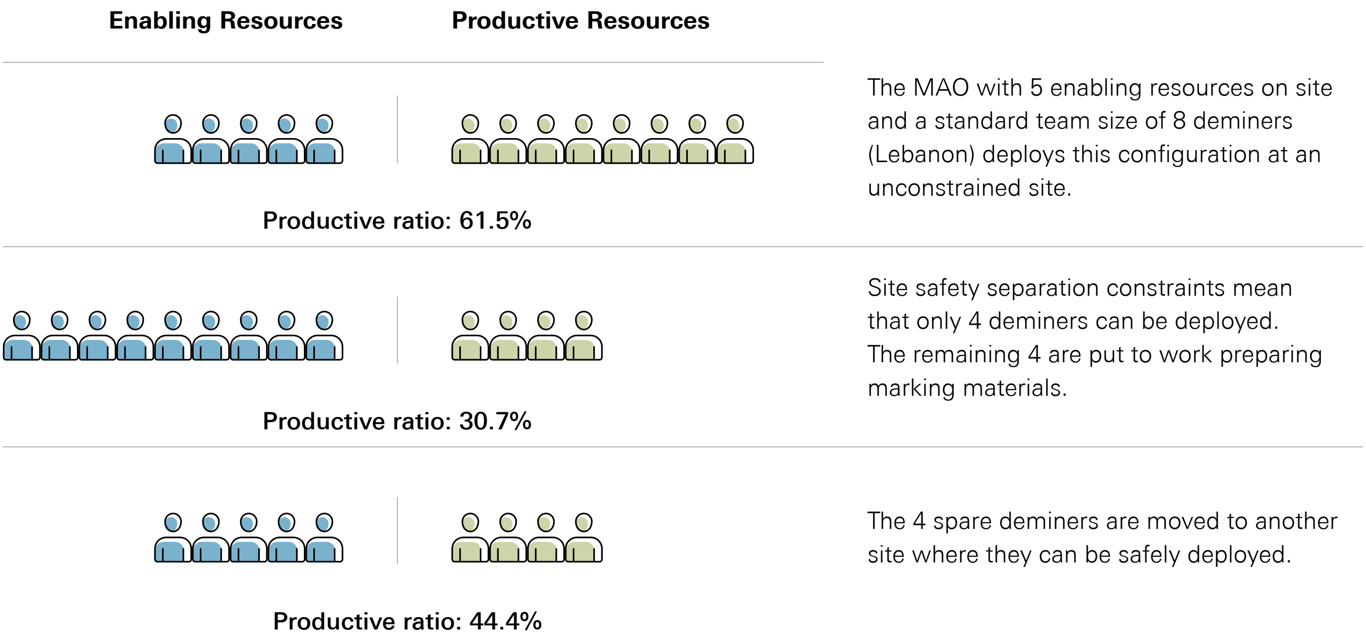
Figure 10: Effect of different team management policies on the productive resource ratio.



Note: The examples are derived from data collected from three MAOs during case study interviews.

The two examples from Lebanon show how the proportion of potentially productive resources, represented by the number of deminers on site compared to the total number of people on site, can impact efficiency. Deploying demining teams is a complex decision in which many element require consideration. It is essential for mine action managers to understand the productive ratio and the range of decisions they can take to ensure that the potentially productive capacity is optimised without compromising safety.

Figure 11: Productive resource ratio at constrained sites (where the size and layout of the site prevents the deployment of all available deminers when safety separation distances are taken into account).



Note: Examples based on information provided during case study deployments to Cambodia and Lebanon.

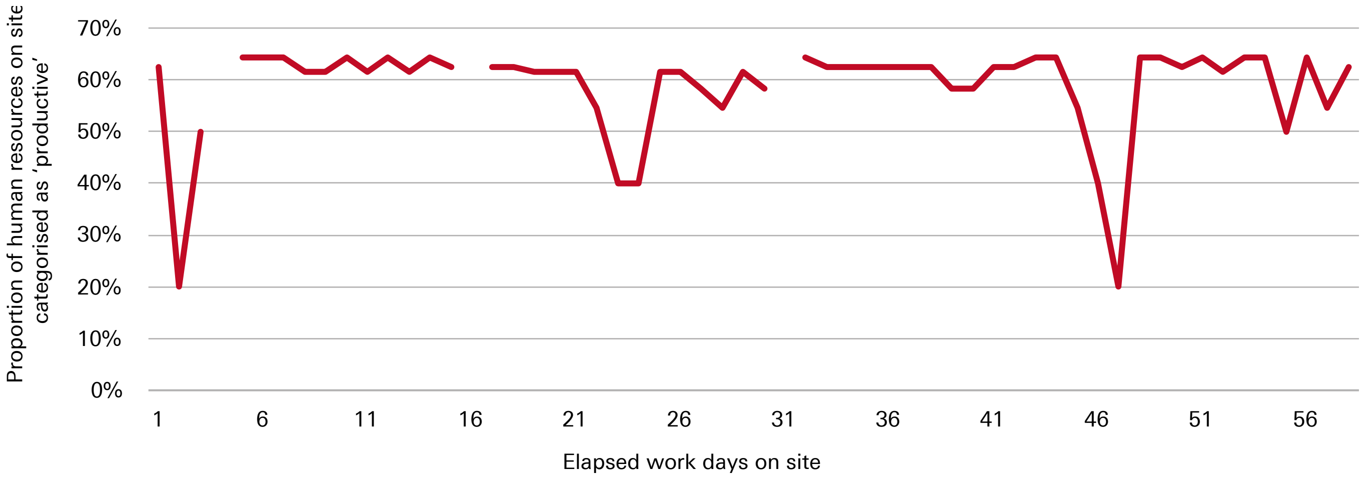
Figure 11 illustrates how decisions regarding the deployment of resource can affect the productive resource ratio at constrained sites. In areas where the geographical size of the task and the nature of contamination impose safety separation restrictions on the number of deminers that can be deployed, decisions about how to use 'spare' deminers have a significant impact on the productive resource ratio.

IMAS guidelines recognise that there may be situations where it is not practical to provide dedicated first aid or medical staff to small demining teams, especially those operating independently and in remote locations over extended periods. In such cases, demining organisations shall ensure that the small demining team has people with first aid training and the resources required to respond to accidents, as well as sufficient staff to manage emergency procedures.

During some of the interviews, implementing organisations reported challenges related to amending operational plans linked to a specific donor project, grant or other contractual agreement. In some cases, amendments to the work plans had to be submitted for clearance to continue, leading to delays and increased downtime, which can negatively impact certain KPIs. In particular, restrictions on personnel transfers to other sites where teams funded by other donors were working were reportedly in place. Despite the administrative reasons behind such restrictions, they can seriously affect the overall productive efficiency of demining teams.

Some contracting methods used in certain countries set a target of square metres or specific area cleared. While this approach may have advantages in areas where hazard boundaries are well-defined, it could prove counterproductive in areas where hazard boundaries are less clear. In these areas, MAOs may have little incentive to use their resources more efficiently. If MAOs are paid by the area of land cleared, they may limit their effort to determine first whether a hazard is present in the suspected area.

Figure 12: Productive resource ratio at one clearance site in Lebanon over a period of 55 days.

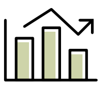


Note: Data collected from inspection of daily diaries from one work site during a case study field deployment to Lebanon.

Figure 12 shows how the analysis of productive resources translates into the day-to-day operations of a work site. The breaks in the data line represent days where no operations took place. On most days, 61.5% of the personnel on site were engaged in a productive activity – demining. However, on several days the ratio dropped significantly, sometimes as low as 20% (with only one in five personnel on site engaged in direct output-generating activity). While there were reasons why it was not possible to deploy the full team on those days (relating to site set up and reconfiguration periods), mine action managers should be aware of the effect of such situations on operational efficiency.[16]

Many MAOs use standard team sizes and structures. For the purposes of this analysis, contextual data was collected from MAOs to generate comparative KPIs. Still, to examine the dynamics of operational efficiency in more detail, it is important to understand how team size translates into actual productive capacity on site on any given day.

Unit productivity



Unit productivity measures the rate at which output is generated. Like for the other KPIs, units of measurement should be unambiguous. In this study, productivity rates are therefore presented as either square metres per deminer per hour or square metres per deminer per day. To facilitate comparison, the results for each day have been normalised to a standard six-hour day. While the same analysis can be applied to ADS and mechanical systems, this study focuses on human productivity. Data is more widely available for human performance, and it is easier to achieve an acceptable level of comparability between data from different countries and MAOs by using contextual data.

Square metres of land cleared or released per asset per day

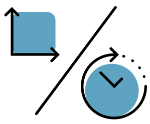


Figure 13 shows the distribution of daily output (normalised for a six-hour day) across the global data set meeting the KPI inclusion criteria.[17] The analysis counts the number of sites falling within data bins. The bins break down the results into blocks of results. Bin 1 counts all sites where the average KPI result was between 0 and 5 square metres per deminer per day. Bin 2 counts all those between 5 and 10 square metres per deminer per day, and so on. The occurrence column height indicates what proportion of counted sites fell within each bin.

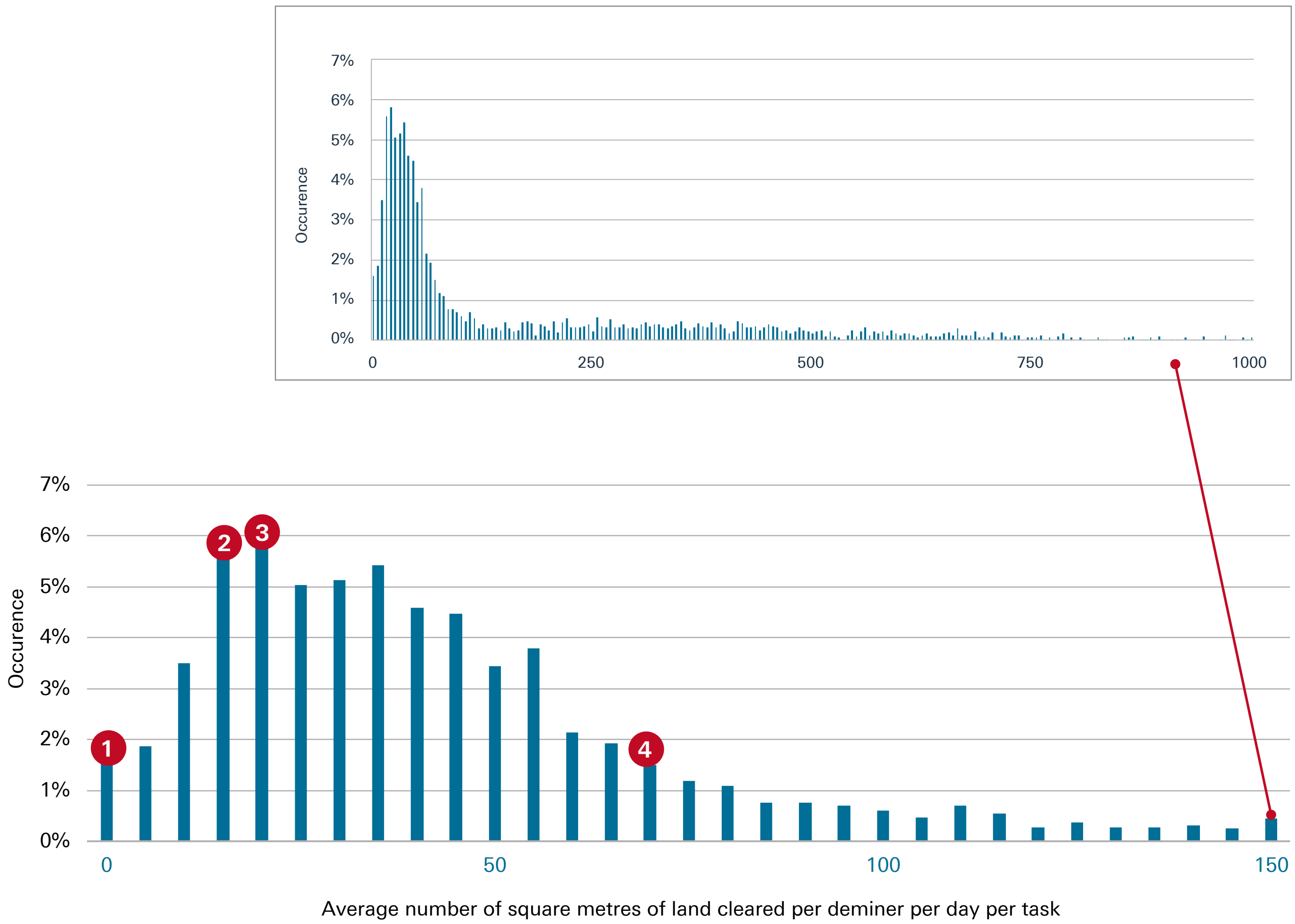
The most common productivity rate among the data analysed is between 20 and 25 square metres per deminer per day. Higher rates, reaching hundreds to thousands of square metres per day are associated with BAC activity that include large loop detection sweeps. On the other hand, lower rates are associated with CMR tasks (in many cases, a specific form of BAC) and landmine clearance work.

The restricted scale of the study prevented a detailed disaggregation of the data by specific clearance methodology, technique or tool. Yet, it is possible to link specific activities to different productivity rates. Four example sites out of the 2,024 site records are highlighted in Figure 13 with numbers 1 to 4. They all involved the clearance of mines and illustrate some of the relevant factors affecting deminer productivity.

[16] One MAO imposed a requirement for a minimum of five deminers on site, even if only one deminer could be actively employed in clearance work, to ensure that any casualty could be carried out by stretcher in the event of an accident. The MAO has prioritised safety in developing the policy; however, this approach can have considerable effects on overall operational efficiency.

[17] The inclusion criteria included the presence of data in specified fields relating to the duration of operations on site, total clearance figures, and the availability of contextual data relating to working hours, days and team size, to allow normalisation.

Figure 13: Frequency of occurrence of square metres cleared per deminer per day.



Note: The study's data set consists of 3,117 site data points from 15 countries, provided by eight MAOs, of which 2,024 data points fall within the chart axis. The full distribution of results is shown in the embedded chart. Numbers 1, 2, 3 and 4 indicate the position on the chart of example sites discussed in the text.

Task 1 had the lowest daily clearance rate and was associated with manual clearance of difficult ground and a hard-to-detect mine threat. Tasks 2 and 3 lie within the most frequent band of output. Task 2 involved manual clearance of 'bounds' resulting in a greater width of advance than the more common clearance lane.[18] Task 3 involved deminers in traditional clearance lanes, with the added benefit of mechanical vegetation-cutting assistance. Task 4 involved integrated use of ADS, mechanical and human assets.

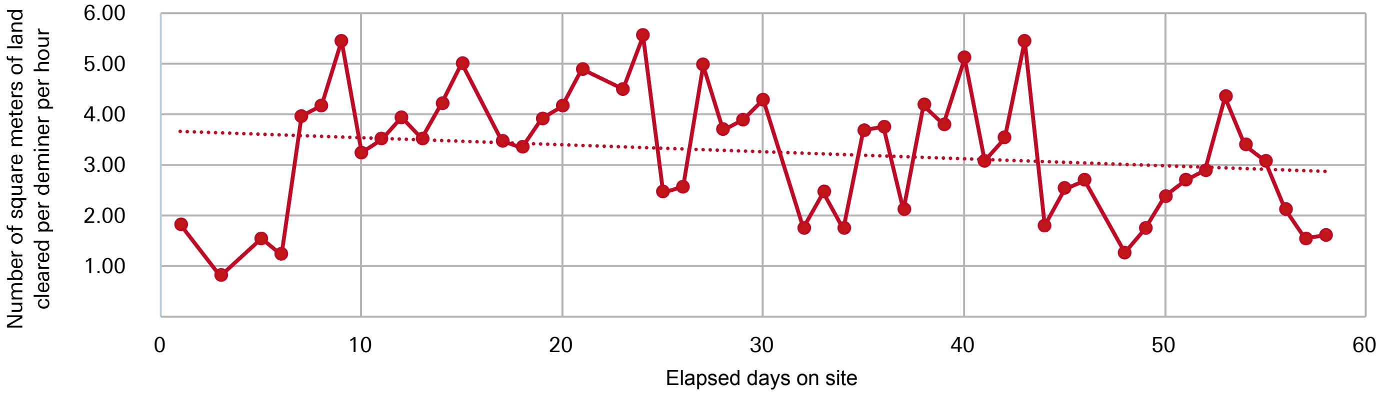
Integrating methodologies can greatly increase the average area cleared per deminer per day. This is the case in Croatia, where a strong focus on the use of mechanical machines and mine detection dogs is visible,[19] and it is reported to substantially contribute to the productivity of operations. In areas with heavy vegetation, mechanical assets are reported to noticeably increase the clearance rates. This observation is reflected in the national mine action policy, which sets the maximum allowed number of square metres cleared by one deminer per day at 400 m^2 (with five working hours per day) and the maximum allowed number of square metres cleared by one deminer per day to 800 m^2 in areas previously processed by mechanical assets.[20] With over 40 working mechanical assets (mostly used for flailing) throughout the country, and an average of 500 deminers working across Croatia at any given time, the mechanical assets are one of the major contributors to productivity and, hence, to the possible issue of resource efficiency, especially in difficult terrain.

[18] A bound is similar to a traditional demining lane, with the exception that it is wider and therefore enables the deminer to clear land laterally instead of creating a breaching lane.

[19] Committee on Article 5 Implementation, "Analysis of the Request Submitted by Croatia for an Extension of the Deadline for Completing the Destruction of Anti-personnel Mines in Accordance with Article 5 of the Convention".

[20] Ministry of the Interior, "Mine Action By-Law Policy on the Manner of Performing Demining, QC, General and Technical Survey and Marking of Mine Suspected Areas", *Narodne Novine*, 2016.

Figure 14: Number of square metres of land cleared per deminer per hour at a single clearance site in Lebanon over 55 days.



Note: Data from daily diaries inspected during the case study deployment.

Figure 14 looks at the variations in the daily average productivity per deminer over the lifetime of a single clearance site in Lebanon.[21] The relatively low figures at the beginning of the period are common for individual sites. Site set-up periods, when work is often interrupted, and the initial time necessary for deminers to become familiar with the site and its conditions, typically result in reduced rates, followed by an increase to a higher overall level until the site is closed. In this case, work started in favourable autumnal conditions and continued through the winter, when poor weather was prevalent, until completion early in the following spring. There is a slight but noticeable downward trend in productivity throughout the lifetime of the task, which may be associated with weather conditions. In total, 97% of the 7,345 square metres of hazardous area was subject to clearance. A total of seven mines were found.[22]

Figure 15: Relative performance of men and women deminers.

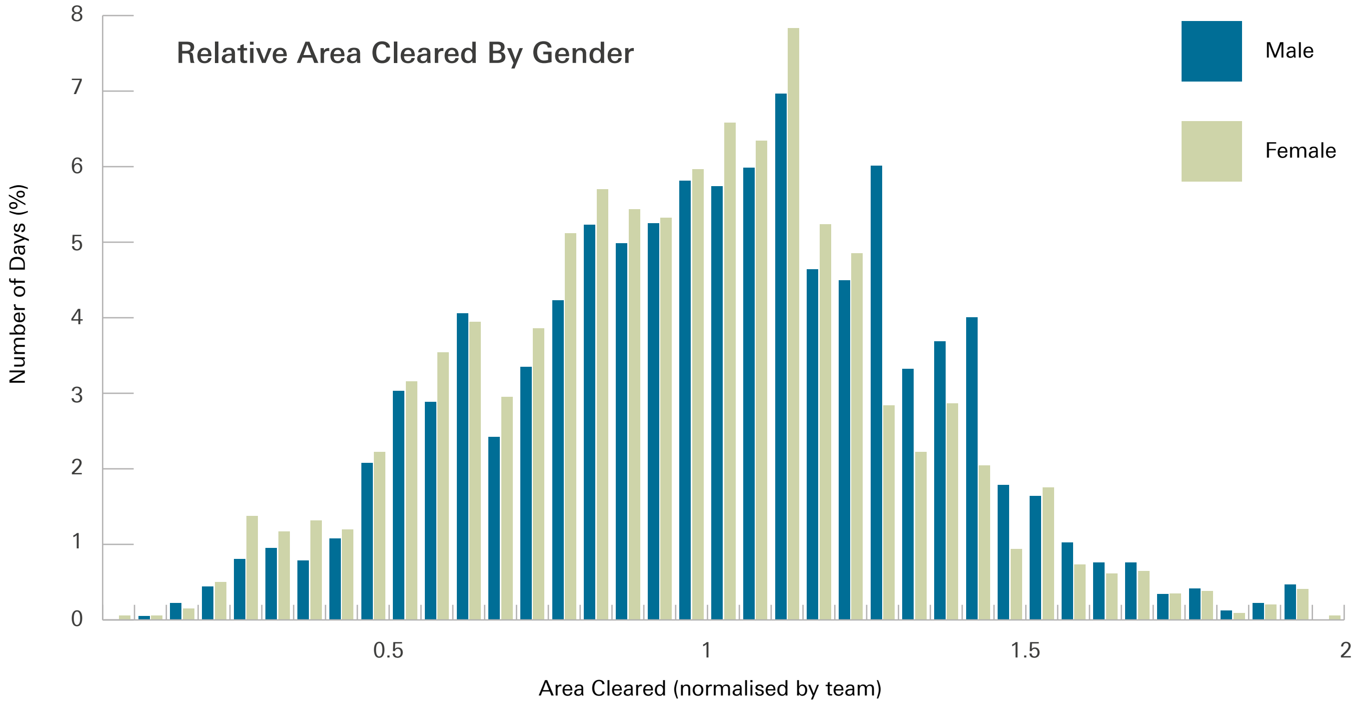


Figure 15 shows the results of an analysis carried out by the GICHD in 2021 on gender and operational efficiency.[23]

It looked at the practical performance of men and women in TS and clearance teams, in terms of square metres cleared per person per day, and at their availability for work. The study used data from 23 mixed teams working in six country programmes to obtain 7,575 data points, each one representing one person's performance on one day. The analysis compared the daily performance of each individual with the average performance of their respective team on that day, to normalise the relative performance of men and women.

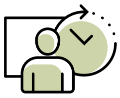
The results of this study indicate that there is no significant difference in terms of operational productivity between men and women working in technical land release operations.

[21] Total number of square metres cleared each day per number of deminers per number of hours worked.

[22] The site was selected for the availability of its data. Operations took place from the fourth quarter of 2020 to the first quarter of 2021.

[23] Raphaela Lark, David Hewitson and Dominic Wolsey, "Gender and Operational Efficiency", Journal of Conventional Weapons Destruction, vol. 26, iss. 1, Article 7 (2022), https://commons.lib.jmu.edu/cisr-journal/vol26/iss1/7/.

Working time



Working time is the final element of the production equation. This study focused on two aspects: the ratio between productive time and total working time, and asset time per item of explosive ordnance found. Productive time is the amount of working time a productive resource spends being productive. A deminer on site for one day does not necessarily engage in productive work throughout that day. Rest and eating times can normally be accounted for relatively easily in any analysis process, but other factors, such as weather interruptions, preparation times, demolition interruptions, etc., can also have a significant impact.

Productive time ratio

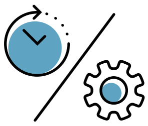
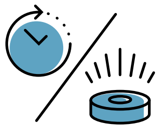


Figure 16 shows the proportion of deminer hours spent on output-generating clearance work, in relation to the number of available deminer hours on site each day. The MAO concerned applies a normal six-hour working day policy, which means that each deminer brings a potential six productive hours to the site each day.

On average, 51% of the theoretically available time was spent on clearance activities. The highest value was 73%, the lowest 3%. The average productive time slightly increased throughout the duration of the task. It is important to clarify that this study does not provide a unique 'right' way to approach site management, nor does it suggest benchmarks or targets for MAOs and authorities to pursue. Many circumstantial reasons can account for the variations in productive efficiency, and it is important that mine action managers monitor the situation and understand the impact of their decisions on operational efficiency. Also, the GICHD study on gender and operational efficiency cited above demonstrated that there is no significant difference in the availability of men and women to work.[24]

Cost analysis is addressed in more detail below. However, productive assets have a cost whether they are working to clear land or not. Consequently, a low proportion of productive time means that the public funds allocated to the programme deliver less benefit to the affected population.

Deminer days spent per item of explosive ordnance found

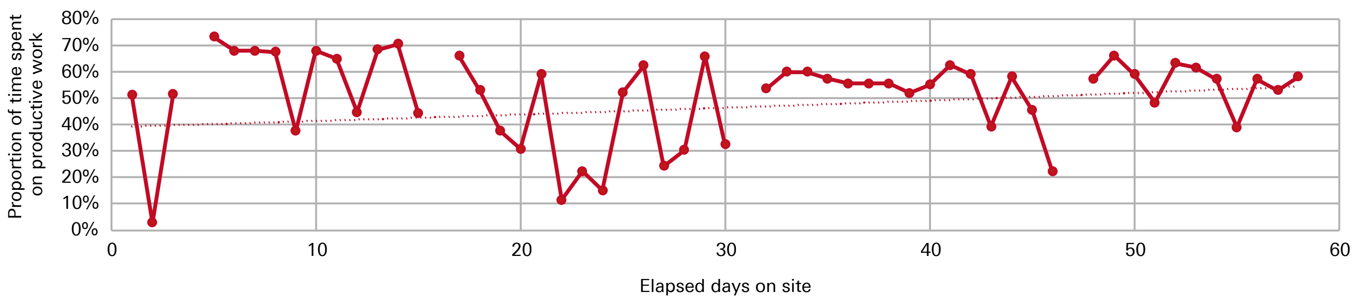


The deminer days per item of EO found is closely related to the number of square metres of land cleared per item of EO found. It provides an indication of how much time is spent clearing land that contains EO. Clearance operations that cover large areas containing few items of EO yield higher values. This indicator does not apply to sites where zero items of EO were found (it would give an infinite value). In this study, 32% of sites for which data was made available reported that no EO was found.

The mission of deminers, ADS, mechanical systems operators and BAC searchers is to release safe land for follow-on use. Their primary objective is to find explosive ordnance in order to declare with confidence that the area is free from hazards. Since mine action resources are expensive to train and deploy, they are best use in areas where EO is likely to be found while spending as little time as possible in areas with no hazards.

Figure 17 shows the frequency of occurrence of KPI results for the number of deminer days per mine.[25] To avoid distortions of the results at sites where few mines were found, but other types of EO were present, only sites where mines made up more than 75% of the reported EO were included. As for the analysis of individual deminer productivity described above, this analysis counts the number of sites where the KPI result falls within data bins (from 0 to 5, 5 to 10, etc.).

Figure 16: Proportion of deminer hours spent on productive work (generating output) at one example site in Lebanon.

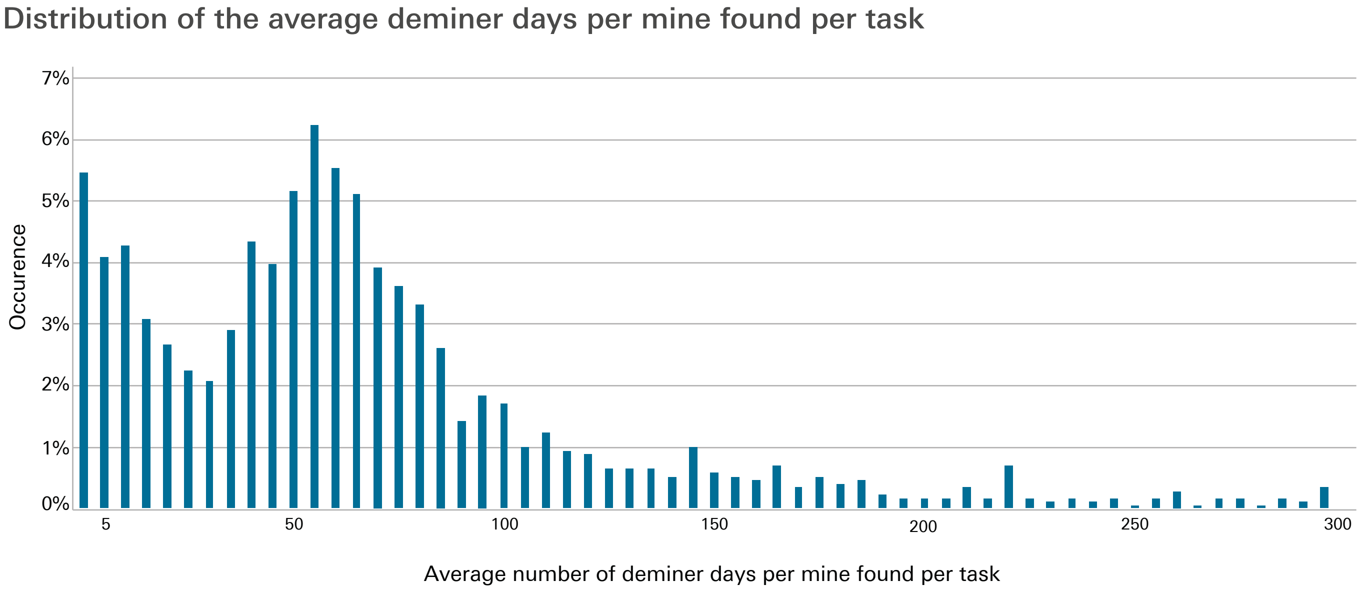


Note: Data from daily diaries inspected during the case study deployment to Lebanon.

[24] Raphaela Lark, David Hewitson and Dominic Wolsey, "Gender and Operational Efficiency", Journal of Conventional Weapons Destruction, vol. 26, iss. 1, Article 7 (2022), https://commons.lib.jmu.edu/cisr-journal/vol26/iss1/7/.

[25] Figures include all mines, AP and AV.

Figure 17: Frequency of occurrence of deminer days per item of explosive ordnance found.



Note: The data set for the study contained 1,681 data points in total, of which 1,546 are represented on this chart, from 15 countries. Data provided by eight MAOs. The analysis does not include sites where no EO was found.

A peak of very low numbers on the left of the chart (between zero and five deminer days per mine found) is associated with sites where very large numbers of mines were found (in one case, over 10,000). The highest number of deminer days per mine, not displayed on this chart, was 7,348 and several sites returned results of over 2,000 deminer days per mine.

A typical working year consists of around 220 days. Therefore, for a demining team consisting of 10 deminers, a working year is around 2,200 deminer days. Several sites reported that more than a team year had been spent working to find each mine. The highest figure represented almost three team years of work to find one mine. After further discussions with operators, the outliers identified in this analysis were due to operators expecting to find a larger pattern of mines than they actually did (only one or two mines).

Table 2: Summary of proportion of cumulative deminer days per mine.

Deminer days per mine	Cumulative proportion of results
Fewer than 20	15%
Fewer than 40	25%
Fewer than 60	43%
Fewer than 80	59%
Fewer than 100	69%
Fewer than 125	75%

Note: The data set consists of 1,681 data points from 15 countries.

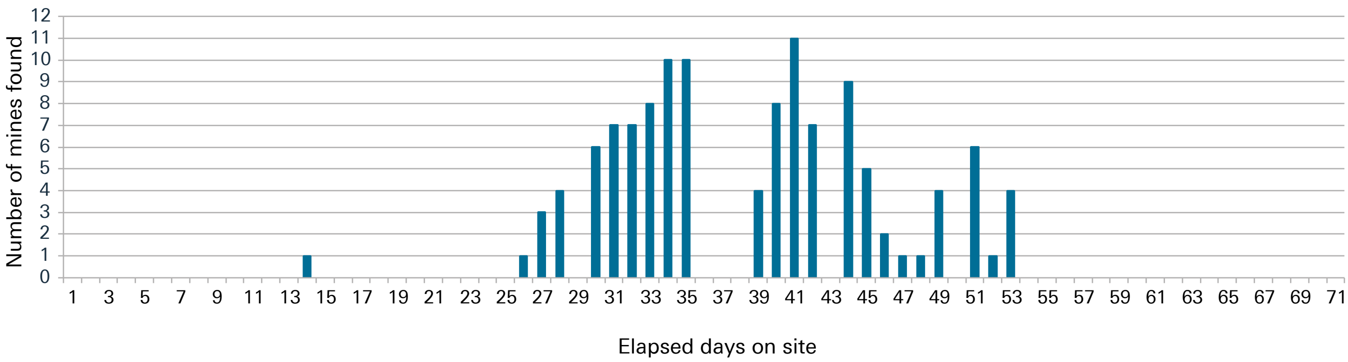
As Table 2 indicates, at 75% of the sites in the study, one mine was found in under 125 deminer days; and in 25% of them, under 40 deminer days or less. For a team of 8 deminers, 40 deminer days equals 5 team days. Therefore, at 25% of sites, a team expects to find at least one mine each working week. Similarly, at 15% of the sites in the study, teams expect to find a mine every one or two days.

Yet, the reality is more complex and results are not as linear. At sites with a large number of mines, periods alternate when mines are found frequently (several times a day by each deminer), and when few or none are found. This can occur either during initial TS or when clearing buffer or fade-out zones after passed through the mined area.

Figure 18 illustrates the mine-finding profile from an example site on the Falkland Islands/Malvinas. Mines were laid in rows within a fenced SHA boundary. However, a period of TS work at the beginning of the task found one mine well outside the main pattern (it was later discovered that it had been displaced by incoming naval gunfire). Eventually, the main mine rows were found and full clearance began. Mines were then found in large numbers every day.

A fenced SHA boundary on the Falkland Islands. *Photo credit © Fenix Insight Ltd*

Figure 18: Profile of the number of mines found each working day, over 71 days, at a site in the Falkland Islands/Malvinas.



As the clearance assets move through the mine rows, the find rate declines until no more mines are found. During this time, though, confirmation clearance of adjacent areas is underway. The average for the site was 5.59 deminer days per mine found.[26]

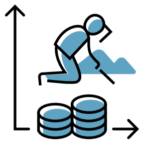
Cost analysis

Cost analysis was conducted at the country level, using a combination of all-up cost data provided by NMAAs, MAOs and open sources, with supporting information about base costs, such as deminers' salaries, provided in questionnaire responses and during case study investigations. While it is possible to conduct a detailed financial audit of costs at a single site, this was outside the scope of this study. The cost analysis therefore only included the overall average cost in USD per square metres released and cleared, based on open-source data and data provided by NMAAs and MAOs. Where more than one source of data was used, NMAA sources were preferred, unless there was a significant discrepancy between sources.[27] Where NMAA data was not available, MAO data was used instead. Where neither NMAA nor MAO data was available, open-source data was used directly in the analysis.

[26] SA064 Site Implementation Plan – 130328 Final, Section 5.2 Management Review.

[27] In South Sudan, analysis of data from the Landmine and Cluster Monitor (USD 0.37) and from MAOs (USD 0.49) tallied relatively closely, whereas the NMAA figure (USD 2.00) was considerably higher.

Cost per square metre of land released



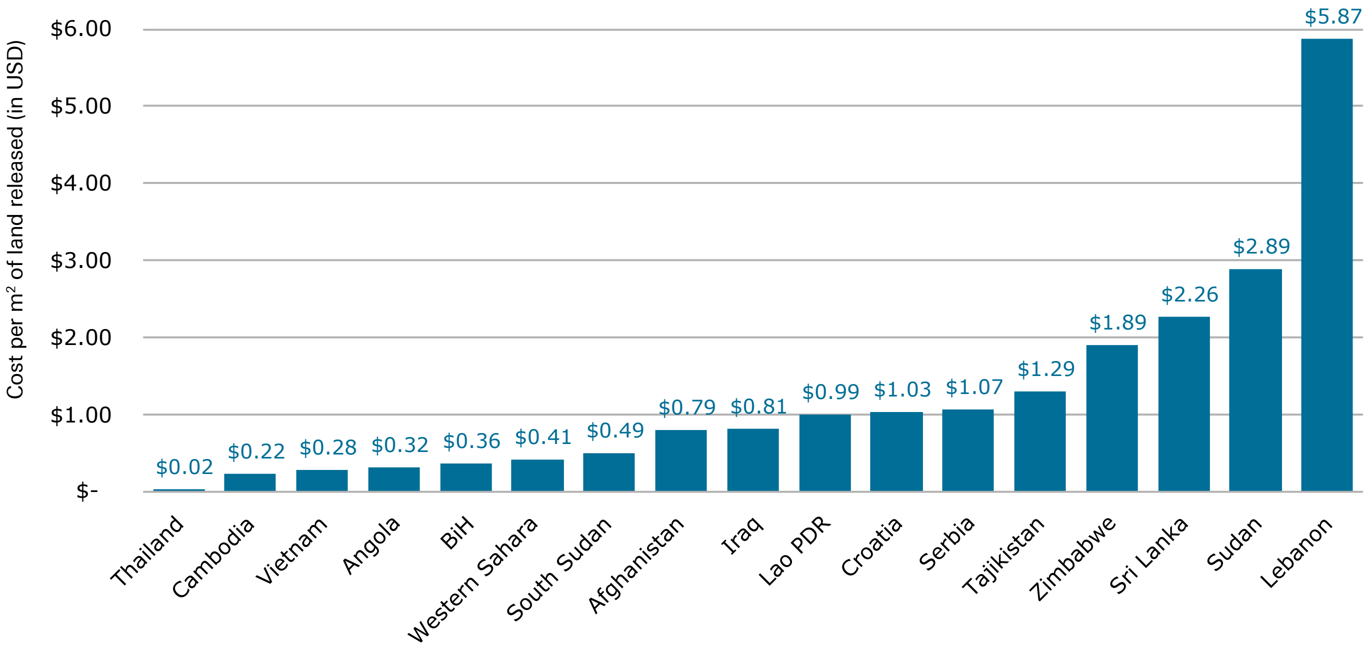
Land released is an output of mine action activity but also an input for subsequent activities such as livelihood activities implemented by communities' post-conflict. The cost of land release is an important measure of cost efficiency in mine action, as it represents the all-up cost of delivering land that can be used for reconstruction, resettlement and economic development.

Figure 19 presents the cost in USD per square metre of land released in 17 countries. The highest value of USD 5.87 per square metre is 293 times as high as the lowest value of USD 0.02 per square metre. The cost of releasing land is partly driven by the cost of the resources engaged in the process, as well as policy and decision-making aspects in many countries.

The proportion of land released through clearance, reduction and cancellation varies among countries, reflecting different approaches to generating each type of output.

Clearance involves the processing of every square metre by an asset – human, animal or mechanical – which drives up costs. In comparison, only a portion of land reduced needs to be physically visited by TS or a clearance asset, while cancelled land need not be physically entered at all. Countries where most land is cleared, such as Lebanon, can therefore expect higher unit costs for each square metres released due to higher operating costs. Conversely, countries like Angola and Thailand, where large areas are released through cancellation, are likely to see lower unit costs due to extensive resurvey processes.

Figure 19: Average cost in USD per square metre of land released (average value USD 1.23).



Note: The results are based on open-source data for six territories, on NMAA responses for six territories, and on MAO data for five. Colombia, not shown on this chart, has an average cost of USD 47.00 per square metre of land released.

Lebanon has the highest cost per square metre released (USD 5.87), 26 times as high as Cambodia, which has one of the lowest (USD 0.22). Several factors may influence these differences, as illustrated in Table 3. Deminer salaries in Lebanon are five times as high as in Cambodia, while the average site supervisor salary is three times as high. According to data from the International Labour Organization (ILO), average earnings per employee across the country are three times as high in Lebanon as in Cambodia. Deminer salaries, although slightly higher than the average earnings per employee in Cambodia (by 1.08 times), are about twice as high as the earnings of an average employee in Lebanon (by 1.7 times).

Team composition is different in Lebanon and Cambodia. The average total monthly salary for a team in Cambodia is USD 3,298 whereas it is USD 21,588 in Lebanon. The cost of a team in Lebanon is six times (6.5) as high as in Cambodia. On average in Lebanon, 66% of salary costs are for productive resources while that number increases to 72% in Cambodia.

In Cambodia, for an average of nine deminers, three enabling resources are provided whereas, for the same number of deminers, five enabling resources are on site in Lebanon.

Table 3: Deminer and supervisor salaries (data collected during case study field visits) compared with minimum and average wages in Cambodia and Lebanon (using data from the ILO).

	Deminer salary [28] (in USD)	Supervisor salary [29] (in USD)	Minimum wage [30] (in USD)	Average earnings per employee across the country [31] (in USD)	Average earnings per employee versus deminer salary
Cambodia	279	594	182	257	x 1.08
Lebanon	1,363	1,849	448	780	x 1.7
Difference	x 4.9	x 3.1	x 2.46	x 3	

One of the factors influencing this difference is the use of deminer medics. Deminer medics are deminers who are trained to provide the same first-aid assistance as regular field medics. In Cambodia, one of the main operators employs deminer medics, while in Lebanon, all operators currently employ dedicated medics as deminer medics are not yet an option. Another factor that operators may influence is the number of deminers and enabling staff deployed depending on the task characteristics. Some operators mentioned splitting up teams when there was not enough space on a task for all deminers to work at the same time. Critically, assessing team composition and remaining flexible plays into operational efficiency. Lower deminer salaries and flexibility in team composition are both likely to increase the overall quantity of land released by enabling a higher number of core productive resources within overall personnel expenditure.

On average, between 2015 and 2019, a deminer in Cambodia released 11.3 times and cleared 6.4 times as much land as a deminer in Lebanon. Although it is difficult to identify the exact reason for this difference, it is possible to identify factors that may influence these figures.

First, both countries face challenges linked to terrain. In Cambodia, dense vegetation affects operational efficiency by reducing individual productivity rates, as it must be removed before a detector can be used. The clearance of vegetation, and other nature-related obstructions can very often be more time -consuming than the actual process of finding mines.

In 2013, the Cambodian Mine Action Centre reported that removal of reeds, bamboo and other vegetation took up to 70% of the time spent on mine clearance.[32] To reduce the effect of vegetation on survey and clearance rates, operators have implemented several solutions. These include the use of mechanical assets, such as strimmers, to prepare bounds[33] or the use of mine detection dogs (MDD), which can move through the undergrowth, thereby reducing the additional effort of cutting vegetation. A study conducted in Cambodia compared data from 190 individual manual demining lanes cleared over a 12-month period, with output data from 43 minefields with vegetation cutting conducted by 11 different machines. The output received from lanes cleared of vegetation using mechanical assets was compared to outputs using manual cutting tools. The results showed an average increase of 73.8% in demining lanes where the vegetation was previously cut using mechanical cutting arms.[34] The use of mechanical assets in Cambodia has continued to increase, and operators using adapted assets can mitigate the effect of vegetation on operational efficiency.

In Lebanon, the challenges posed by the terrain are more difficult to mitigate. In certain parts of the country, terrain can be characterised by steep rocky slopes and dense vegetation. A joint study is currently underway by the Lebanon Mine Action Centre (LMAC) and the GICHD to determine how best to address CMRs in especially difficult terrain. Examples of difficult terrain are deep canyons or very steep cliffs.[35] Uneven, rocky terrain can present a challenge to unit productivity and safety, as explosive ordnance may be hidden between the rocks and rubble, making clearance slow and complicated.

---

[28] Salary figures are extracted from case study data.

[29] Salary figures are extracted from case study data.

[30] Salary figures are extracted from https://ilostat.ilo.org/data/country-profiles/ and were collected in 2019. Converted to USD in November 2022.

[31] Salary figures are extracted from https://ilostat.ilo.org/data/country-profiles/ and were collected in 2019. Converted to USD in November 2022.

[32] T. Ueno, K. Amemiya, M. Ikuta and O. Nishino, "Mine-Clearing System for Use in International Peacekeeping", Hitachi Review, vol. 62, no. 3 (2013): 224–228, https://www.hitachi.com/rev/pdf/2013/r2013_03_102.pdf.

[33] A bound is similar to a traditional demining lane, with the exception that it is wider and therefore enables the deminer to clear land horizontally instead of creating a breaching lane.

[34] GICHD, "Chapter 4. The application of machines in ground preparation", A Study of Mechanical Application in Demining, 2004, https://www.gichd.org/fileadmin/pdf/publications/Mechanical_study/Mechanical_study_chapter4.pdf.

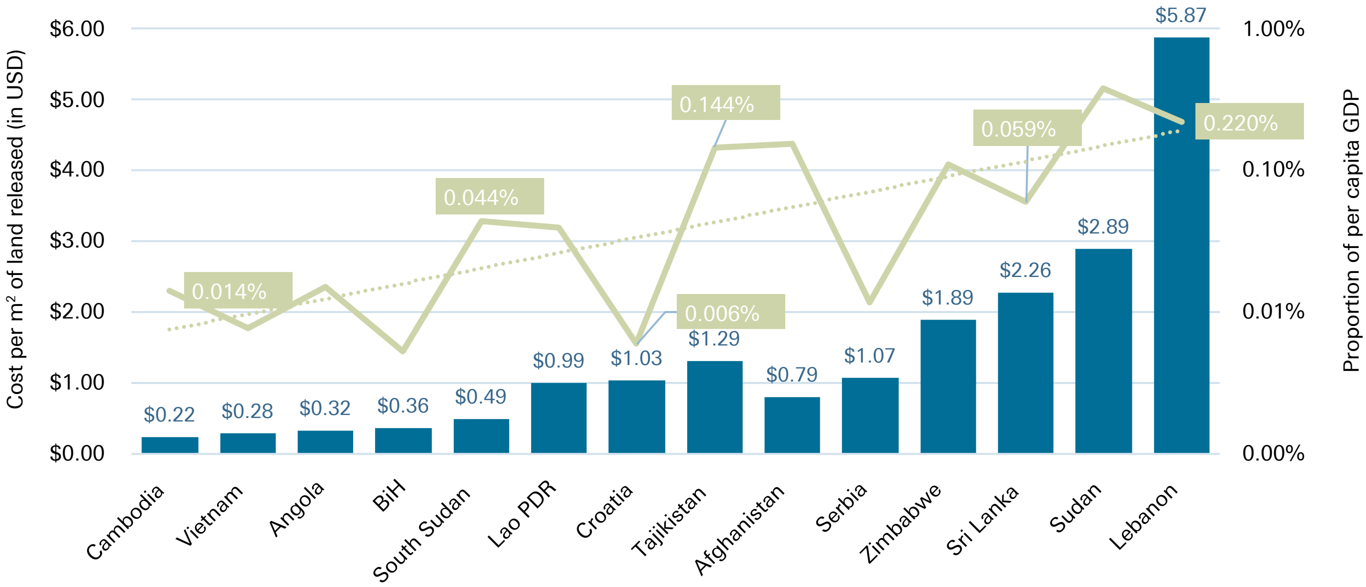
[35] "Lebanon", Mine Action Review, accessed September 27, 2022, https://www.mineactionreview.org/country/lebanon.

Second, several innovative methods have been trialled in Cambodia. For example, dual sensor detectors were a great success and have now been fully implemented by one of the main operators, whilst another is currently working towards implementing it. Several innovative methods involving the use of mechanical systems have also been recently implemented in Lebanon. However, as the data was collected between 2015 and 2019, their benefits may not yet be reflected in clearance statistics. For instance, the LMAC has reviewed and adopted recommendations from an external study commissioned in 2020 on operational efficiency.[36] The gap between Cambodia and Lebanon may therefore have decreased since then.

The fact that land released can produce such different subsets of output in such different ways makes it difficult to draw direct comparisons between countries. The study examined contextual indicators for overall costs in each country, such as the per capita GDP. The country with the highest recent per capita GDP is Croatia (USD 17,398.80), whereas the one with the lowest is Afghanistan (USD 516.70). Yet, the cost per square metre of land released does not vary as drastically between the two countries as the per capita GDP, with Croatia at USD 1.03 per square metre and Afghanistan at USD 0.79 per square metre.[37] The nature of contamination and its distribution in Croatia offers more opportunities to apply efficient reduction and cancellation processes than in Afghanistan, where areas may be contaminated with widely dispersed explosive ordnance, both manufactured and improvised. The higher cost base in Croatia is outweighed by the greater opportunities to apply land release decision-making principles.

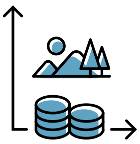
Figure 20 shows how, on a logarithmic scale, there is some evidence of a relationship between the relative wealth of a country and the proportional expense to release land. The cost per square metre of land released increases in absolute terms as well as in relative terms, becoming a larger proportion of the GDP per capita.

Figure 20: Cost per square metres of land released, in USD, as a proportion of per capita GDP.



Note: The per capita GDP was extracted from the World Bank Data. For the cost per square metre, NMAA data was used for six territories, MAO data for five territories and open-source data for six territories. The right axis shows the cost of one square metre of land released as a proportion of the per capita GDP. The average value is USD 1.23 per square metre.

Cost per square metre of land cleared



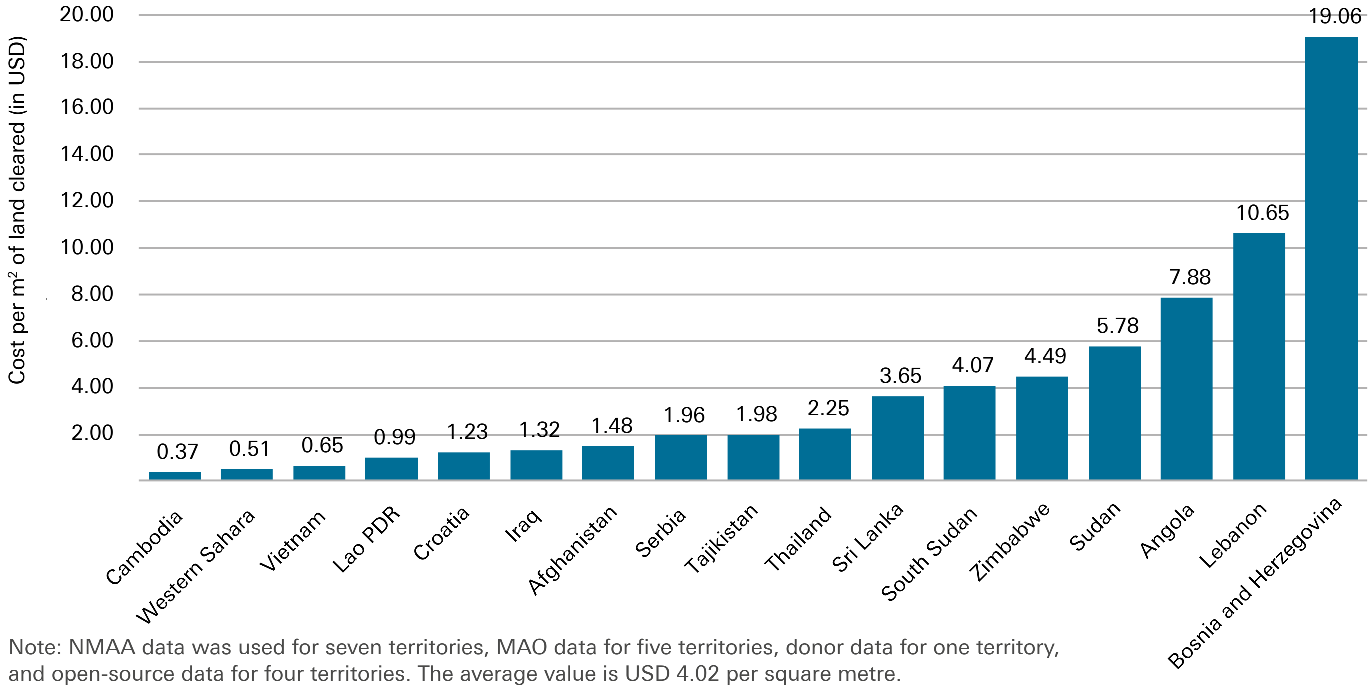
Land cleared involves technical intervention using resources that incur costs, which vary depending on the difficulty of the clearance task (reflecting physical conditions as well as methods employed). Yet, it is reasonable to expect a clearer correlation with underlying resource cost.

A similar spread of results is seen in Figure 21 as in Figure 19, although with higher unit costs as clearing land is more expensive than reducing or cancelling it. Although the ranking of countries across the scale is similar in some places, some changes are particularly striking. These are associated with countries that have high ratios of land cleared to land released – in particular, Angola, Bosnia and Herzegovina, and Lebanon. All three have moved from the lower third of the scale in terms of the cost of land released to the upper half of the scale for the cost of land cleared.

[36] 'Lebanon', Mine Action Review.

[37] GDP per capita figures from www.data.worldbank.org. Figures are available for most recent years.

Figure 21: Cost per square metre of land cleared, in USD.

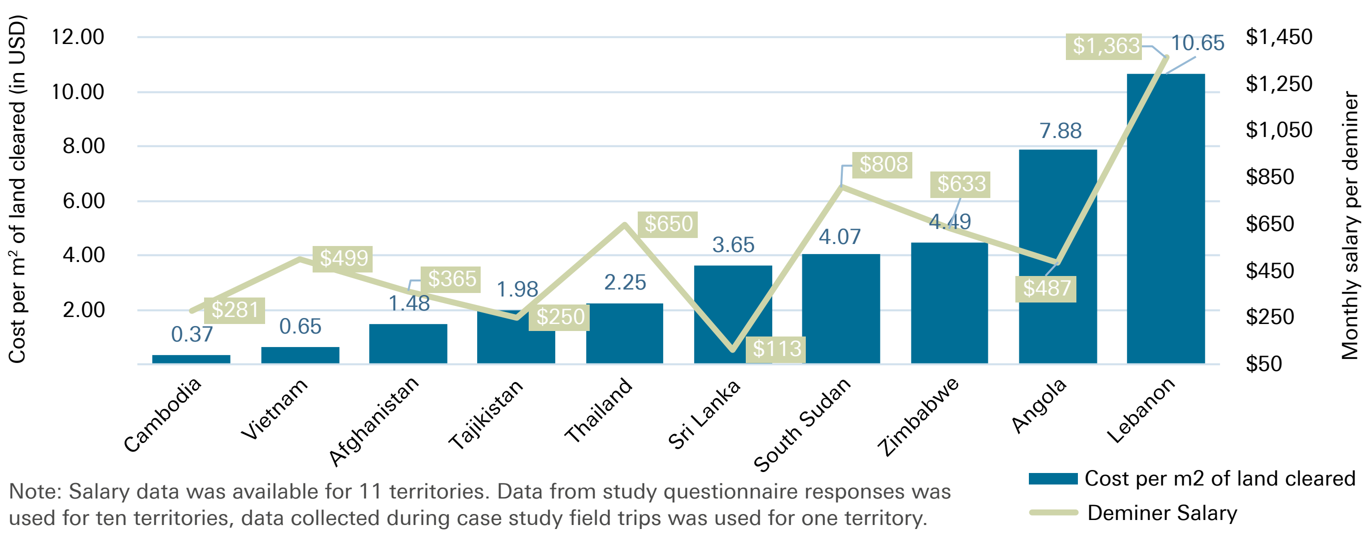


Note: NMAA data was used for seven territories, MAO data for five territories, donor data for one territory, and open-source data for four territories. The average value is USD 4.02 per square metre.

Although this leap in cost may give the impression that land clearance operations may be less efficient than overall land release operations, this is not the case, as KPIs must be read in context. For example, while Bosnia and Herzegovina and Lebanon have the highest costs per square metre of land released, they also have some of the lowest numbers of square metre of land cleared per item of EO found. This indicates that clearance is extremely targeted in these countries. Notably, IMAS state that, the number of square metres per item of EO found "is also influenced by both the effectiveness of the survey and the efficiency of the clearance of a given hazardous area. While differing m²/item figures can often be explained by the type of contamination (e.g. pattern vs nuisance minefield), m²/item remains one of the most basic methods of identifying effective survey and efficient clearance."[38] Thus, regardless of these seemingly high costs, an contextual analysis with other KPIs can determine that operations have been conducted in an efficient manner.

Again, such changes reflect the significant influence that land release policies and circumstances have on the cost per square metre of land released. They also reinforce the expected link between clearance costs and underlying resource costs. Figure 22 explores this correlation by comparing the cost per square metre of land cleared with the average deminer salary for countries where that information was available. While the correlation is not particularly obvious, there is some evidence of a relationship between the cost of a deminer, used as a proxy for the wider costs incurred in each country, and the overall cost to clear each square metre of land.

Figure 22: Cost per square metre of land cleared in comparison to the average deminer salary (in USD).



Note: Salary data was available for 11 territories. Data from study questionnaire responses was used for ten territories, data collected during case study field trips was used for one territory.

[38] Technical Note 07.11/02: Key Performance Indicators (KPIs) for Land Release and Stockpile Destruction Operations.

CASE STUDY

A marked CHA in Croatia. *Photo credit © GICHD*

Croatia clearance rates

Clearance rates are of particular interest in Croatia, as the price per square metre of land cleared has been historically low compared to other countries. The World Bank has been funding mine clearance efforts in Croatia since 1997, at an average cost of USD 3 per square metre of land cleared. In 2003, this cost dropped to USD 1.8.[39] According to the KPIs generated in this study, that cost has remained relatively stable, even decreasing slightly to USD 1.23 per square metre. In its 2009–2019 strategy, the Croatian Mine Action Center (CROMAC) projected that it would cost HRK 4,187,000 to release 756.5 square kilometres of land over 11 years,[40] which is about USD 0.9 per square metre. The land release data received from CROMAC for the 2015–2019 period indicates an average rate of USD 1.03 per square metre, which is marginally close to the planning figure in the strategy – especially given that various currencies (HRK, USD, EUR) are used in the calculation, and that exchange rate fluctuations are not considered.

The cost of clearance has risen slightly over the past few years, which could be an indication that most of the flatter, less problematic areas have been cleared, and that the vast majority of the remaining tasks are in difficult terrain. For example, for the 2022 work plan, it was estimated that a total of HRK 215,000,000 would be required to clear 23,300,000 square metres of land on one of the sites visited by the GICHD, which equals HRK 9.2 (or USD 1.44) per square metre. The clearance rates observed during the visit were compared with the clearance rates of another project (funded by Switzerland) in Kotar-Stari Gaj woods in 2018. Then, 294 deminers had cleared 1.8 square kilometres of land in 39 working days, with an average productivity of 157 square metres per deminer per day, and a cost of USD 1.71 per square metre (according to the exchange rate of USD 0.97 to CHF 1 in September 2018).[41]

A number of approaches to how land release operations are planned and implemented in Croatia, can contribute to the cost per square metre of land cleared. CROMAC's planning, tasking, and decision-making is often driven by geographical factors. During the planning stage, CROMAC uses a combination of topographical maps, digital orthophotos and vector layers that contain mine action and other related data to model the nominal operational difficulty of demining. This helps to determine the size of tasks and the type of suitable assets for a given hazardous area. It also provides more accurate information on the accessibility of planned hazardous areas and deeper knowledge of local terrain conditions. In addition, comparing topographical maps from the conflict period with more modern digital orthophotos allows for identification of terrain changes that might be useful in future planning processes.

Furthermore, a land release method called 'supplementary non-technical survey' has been introduced in Croatia. This hybrid method combines NTS and TS on a smaller scale to get additional insight into a specific suspected area, intending to release this area without using the resources for larger-scale TS or clearance. This is in line with the 'Good Practice Checklist', which provides practical guidance on achieving ARE detailed in TNMA 07.11/03.[42] One of the key good practices for ARE is developing national mine action standards that define key land release terms and processes.

Lastly, a critical factor that contributes to costs in Croatia is the way tasks are allocated during the preparation for tendering, the tendering itself, bidding and the implementation process. Companies operating in Croatia form several consortia for each tender/bid, which take multiple factors into consideration, including the capacities of each member of the consortium and the location of its offices and deminers.

[39] Jacques Buré and Pierre Pont, Landmine Clearance Projects: Task Manager's Guide, Social Development Papers, Conflict Prevention & Reconstruction, Paper No. 10, 2003, https://web.worldbank.org/archive/website00522/WEB/PDF/WP10WEBV.PDF.

[40] GICHD, National Mine Action Strategy of the Republic of Croatia, 2009, https://www.gichd.org/fileadmin/GICHD-resources/rec-documents/NMAS-Croatia-2009-2019.pdf.

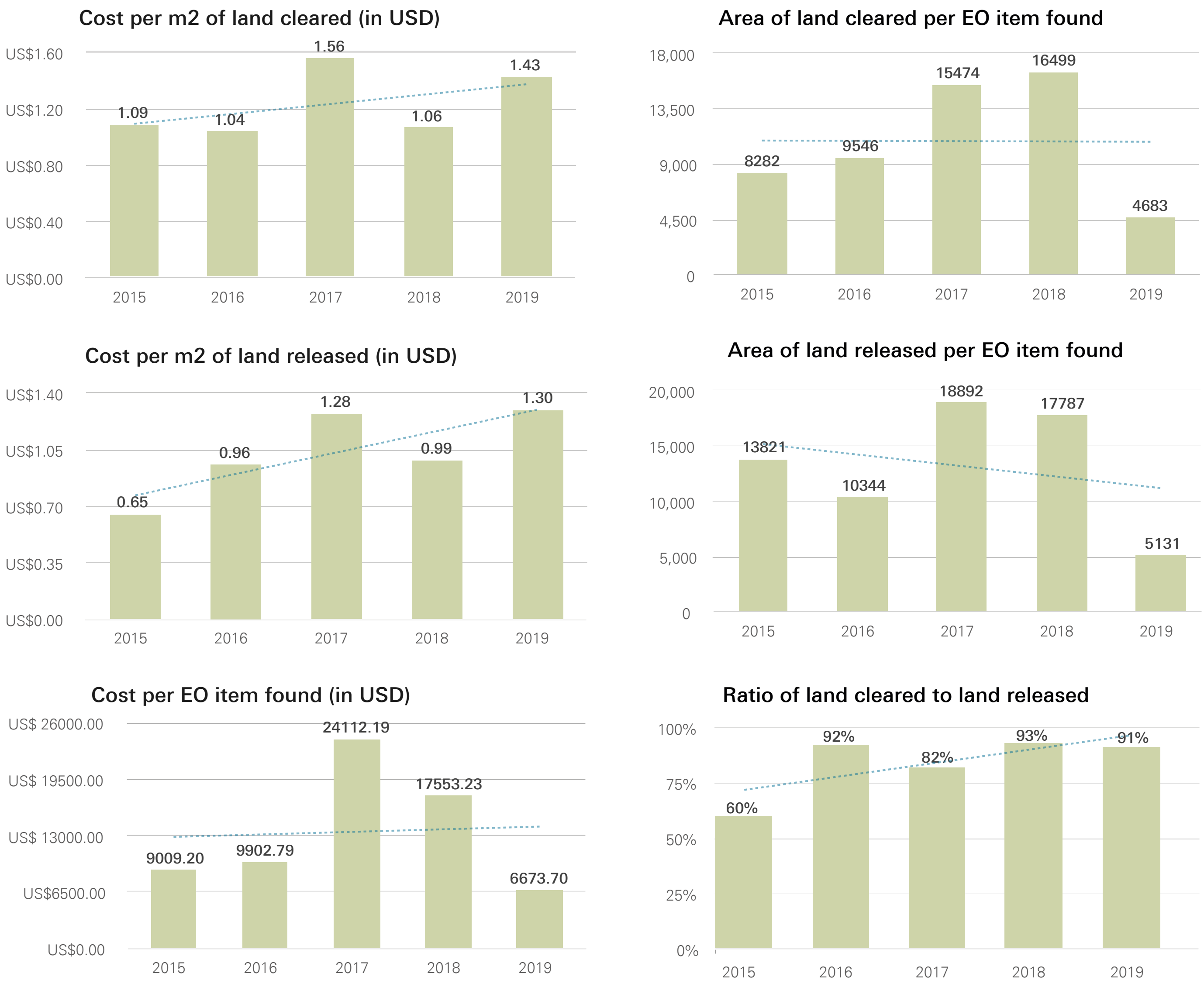
[41] FDFA, 'In Croatia's woods 3,585 mines have been defused', Eda.admin.ch, 12 December 2018, https://www.eda.admin.ch/countries/croatia/en/home/news/news.html/content/schweizerbeitrag/en/meta/news/2018/12/20/erfolgreiche-entminung-in-kroatien.

[42] TNMA 07.11/03: All Reasonable Effort, 2021: 19.

The most important factors are seasonal, environmental and topographical considerations for each site, which prevent operations across the country from being disrupted, with teams and assets deployed sequentially. These seasonal, environmental, and resource-based planning assumptions are also found in CROMAC's multi-annual work plan that the subsequent tendering is based on.

The mine action sector in Croatia is heavily regulated and relies on EU-compliant laws, by-laws and regulations. It is also protected through labour law, law on occupational safety and unions for deminers. Therefore, the comparatively high cost per square metre of land cleared do not seem to raise concerns amongst stakeholders, including demining staff, the government and donors. Furthermore, the criteria and parameters for the implementation of ARE in land release are specified in the 'Regulations on demining, quality control, non-technical and technical surveys and marking of suspected hazardous areas', as well as in conceptual demining plans (defined for every specific project or area). The Regulation is aligned with the Act on Mine Action (now replaced with standard operating procedures).

Figure 23: KPIs in Croatia, by year.



Note: Data provided by the national authorities.

Table 4: Summary of study KPIs for Croatia during the period 2015–2019.

Average cost per square metre of land cleared	Average cost per square metre of land released	Average cost per item of EO found	Average area of land cleared per item of EO found	Average area of land released per item of EO found	Average ratio of land cleared to land released
USD 1.23	USD 1.03	USD 13,450	10,897 square metres	13,195 square metres	84%

Cost per item of explosive ordnance found

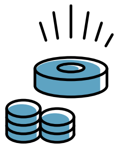
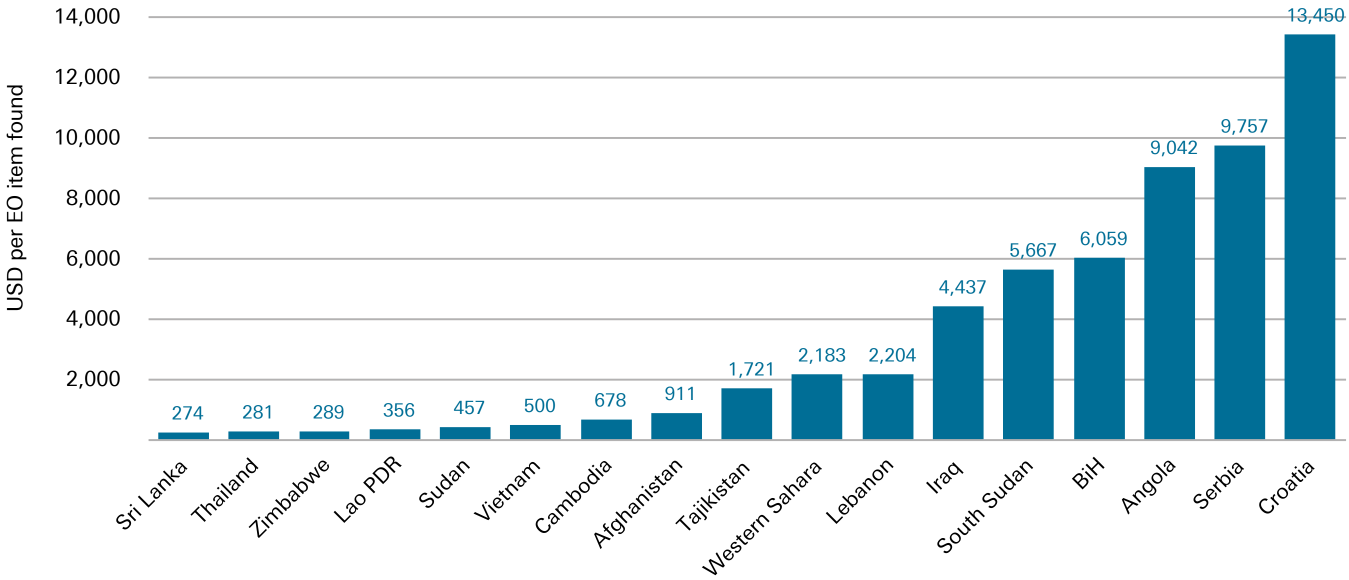


Figure 24 shows the average cost for each item of explosive ordnance found. Zimbabwe, at the lower end of the chart, benefits from very low areas cleared and released per item of EO found, combined with a low average deminer salary. In comparison, South Sudan's middle-ranking cleared and released area per item of EO found, coupled with a relatively higher deminer salary, explains the relatively high cost per item of EO found (excluding Colombia).

Figure 24: Cost per item of explosive ordnance found, in USD.



Note: NMAA data was used for seven territories, MAO data for two territories and open-source data for eight territories. The average value is USD 3,427.

Table 5 shows that the cost per item of EO found is three times (3.3) as high in Lebanon compared to Cambodia. The difference between the cost per item of EO found and per square metre of land released is ten-fold. This means that the cost difference in cost between Cambodia and Lebanon is smaller per item of EO found than per square metre of land released.

As shown above, operators in Lebanon need to process a smaller area of land to find one item of EO than in Cambodia (on average, 349 square metres compared to 3,360 square metres in Cambodia). Cambodia therefore releases nine times (9.6) as much land per item of EO found as Lebanon. Similarly, operators need to clear an average of 1,830 square metres of land per item of EO found in Cambodia, compared to 252 square metres in Lebanon. Cambodia thus clears approximately seven times (7.3) as much land per item of EO found as Lebanon.

Table 5: Comparison of KPIs related to cost and area for Cambodia and Lebanon.

	Average cost per item of explosive ordnance found	Number of square metres of land released per item of explosive ordnance found	Number of square metres of land cleared per item of explosive ordnance found
Cambodia	USD 678	3,360 square metres	1,830 square metres
Lebanon	USD 2,204	349 square metres	252 square metres
Difference	x 3.3	x 9.6	x 7.3

Operators in Lebanon are better able to define the hazardous areas, as many of them are patterned minefields for which maps are available. These maps can accurately predict where mines may be found, allowing operators to target resources efficiently and effectively. Although some 'militia' minefields exist, where mines were laid without a defined pattern by different actors during the civil war and where no minefield records exist,[43] these are often smaller tasks. In Cambodia, hazardous areas are more difficult to define as contamination patterns are less predictable and related documentation is unavailable. The difference in the contamination age also affects the definition of hazardous areas, as local informants in Cambodia are either no longer alive or have since moved.

Beyond these KPIs, it is important for operations to be able to carry out regular analysis of the results of land release.[44] These may allow operations to assess both efficiency and effectiveness of operations and make evidence-based changes to mechanisms/procedures as needed, to improve in these areas. Several country-specific examples also arise. Cambodia and Lebanon monitor efficiency and effectiveness through monitoring and analysing a number of indicators (explosive ordnance accidents, meterage of clearance products, items of EO left undetected in the released land, the number of item of EO found and destroyed) as well as internal and external quality assurance/quality control results. Both countries also engage in weekly monitoring of land release operations by the relevant officers to help improve the clearance plan for each site. Lastly, Lebanon compares the time spent to the number of items of EO detected, assesses the number of released areas achieved during the year and compares it with the previous year's achievements, as well as comparing the land release results to the annual work plan and mine action strategy.

[43] "Lebanon: Clearing the mines 2020", Mine Action Review, accessed 27 September, 2022, https://www.mineactionreview.org/assets/downloads/907_NPA_Clearing_the_Mines_2020_Lebanon.pdf

[44] In line with the Good Practice Checklist providing practical guidance on achieving ARE, in TNMA 07.11/03, p. 19.

A CHA with dense vegetation and hard-to-reach EO in Colombia. *Photo credit © GICHD*

CASE STUDY

Colombia cost data

Based on historic knowledge, as confirmed during this research, Colombia stands out when it comes to some of the KPIs. Their values are significant outliers and, consequently, cost data for Colombia was not included in some figures in this report. Some of the KPIs for Colombia are shown in Table 6.

These outstanding results may reflect the extreme challenges associated with Colombia's many remote, hard-to-access, heavily vegetated and steeply sloped task sites, as well as the hard-to-detect nature of many of the EO hazards. Colombia also shows above-average numbers of square metre of land cleared per item of EO found – a consequence of the dispersed nature of much of the contamination. These factors combined help explain the very high-cost figures associated with Colombia.

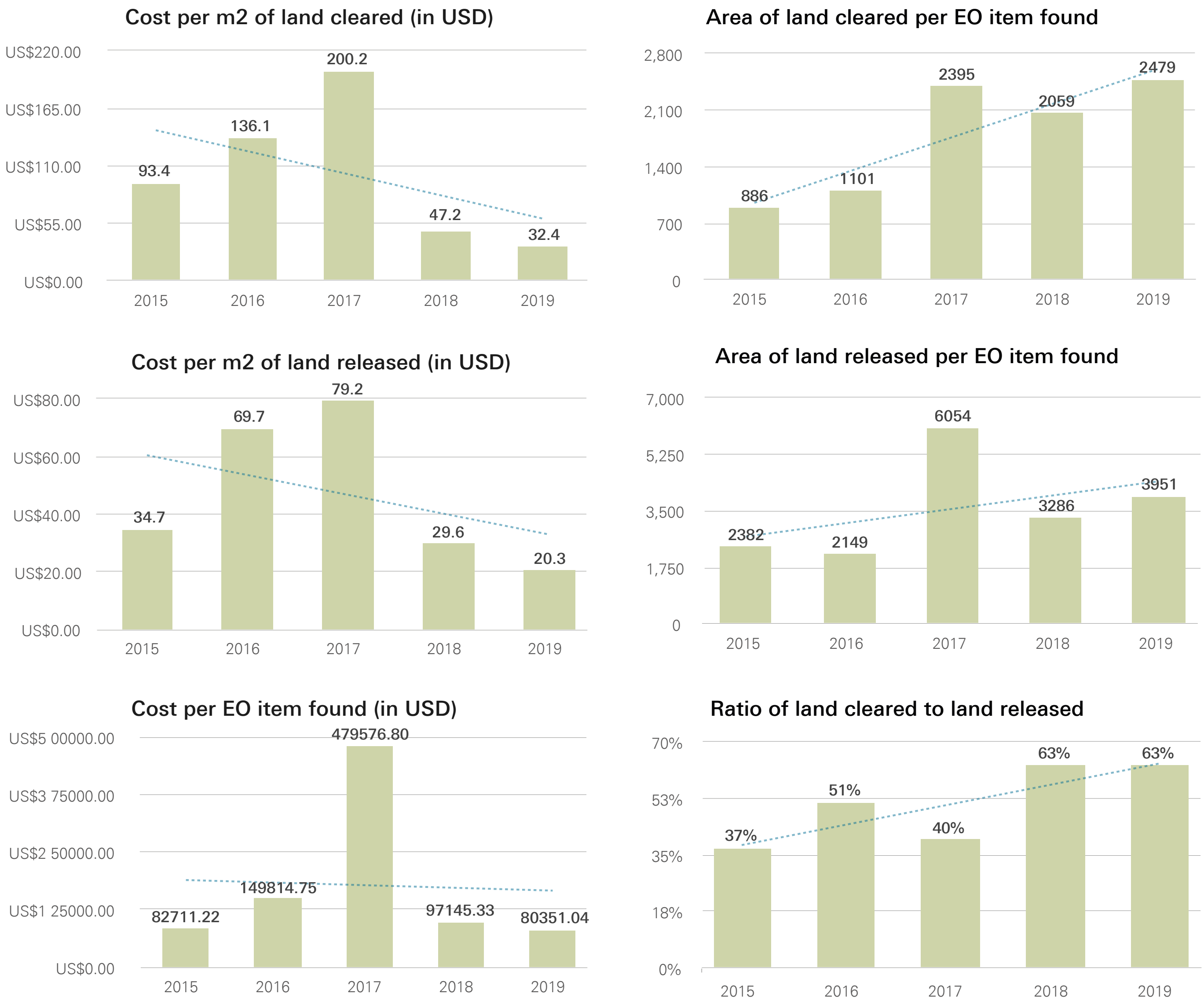
When looking at the annual data for Colombia, there is a noticeable trend in the decrease of cost and in the increase of land released through clearance. This may be because the mine action sector in Colombia is relatively new and a significant effort was made to improve the quality of surveys between 2015 and 2019. Hence, a new generation of non-technical surveyors (NTS) has emerged, who collectively gather high-quality data for efficient and effective land release operations.

An earlier assessment by the GICHD focusing on Colombia suggested that improvements in analysis and evaluation of operational decisions relating to land release through reduction and clearance, especially from a quality management system perspective, can have a major influence on the effectiveness and efficiency of mine action activities. The results of the analysis using efficiency KPIs should contribute to the process of continuous improvement. For example, certain trends and tendencies may be identified and prompt the revision of NTS earlier reports of SHAs and CHAs completed through clearance which did not reveal any real contamination. Further analysis may indicate that a specific type of evidence perceived as direct may not have the same value in different parts of Colombia. In this case, this new information may need to be reflected in internal standard operating procedures or even in Technical Notes.

Table 6: Cost data in Colombia compared to global cost averages.

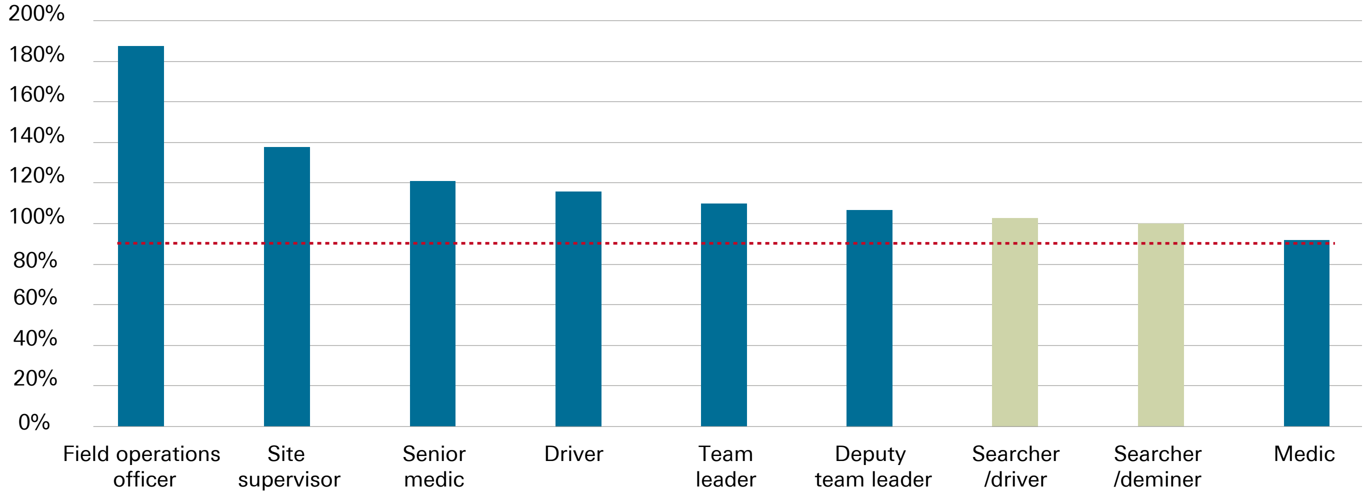
KPI	Average cost per square metre of land released	Average cost per square metre of land cleared	Average cost per item of EO found
Highest value on global chart	USD 5.87	USD 19.06	USD 13,450
Colombia	USD 47	USD 102	USD 175,710

Figure 25: KPIs in Colombia, by year.



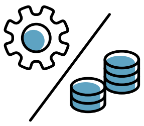
Note: Data provided by the national authorities

Figure 26: Average proportional costs relative to a deminer's salary for MAOs in Lebanon.



Note: Data from three MAOs, averaged across common job functions.

Productive cost ratio



In the same way that productive resource ratio analysis can be run, so a similar approach can be applied to the costs of deployed resources. The analysis drew on detailed data as part of the case study deployments to Cambodia and Lebanon. Figure 26 shows that enabling resources are often associated with higher unit costs than the productive resources, in red. Considering the cost dimension often supports the analysis of the productive resource ratio. Table 7 compares the average ratios between Cambodia and Lebanon.

Cambodia and Lebanon were selected for case studies because they represented the extremes of the cost per square metre of land released KPI in this study. The significant difference in underlying costs, highlighted by the almost five-fold difference in deminer salaries, explains much of the overall differences observed.

The use of productive cost ratios provides managers with another metric to understand the implications of resource allocation and how it affects operational efficiency and the 'value proposition'. However, managers should use caution when using the KPIs so that decisions do not compromise safety. This should be included in ongoing risk management procedures where managers accept a 'tolerable' level of risk and are confident that it is well-controlled and worth taking.

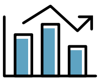
While reducing efficiency in operations in order to respond to external factors beyond their control may sometimes be inevitable, mine action managers should be aware of the cost efficiency implications of their different responses.

Table 7: Illustrative comparison of key cost data and ratios for Cambodia and Lebanon.

KPI	Cambodia	Lebanon	Comparison
Cost per item of explosive ordnance found	USD 678	USD 2,204	x 2.5
Cost per square metre of land released	USD 0.22	USD 5.87	x 26.7
Cost per square metre of land cleared	USD 0.37	USD 10.65	x 28.8
Deminer salary	USD 279	USD 1,363	x 4.9
Site supervisor salary	USD 594	USD 1,849	x 3.1
Team enabling resource cost percentage	28%	34%	-
Team productive resource cost percentage	72%	66%	-

Note: Average results from two MAOs in Cambodia and four MAOs in Lebanon.

Economies of scale

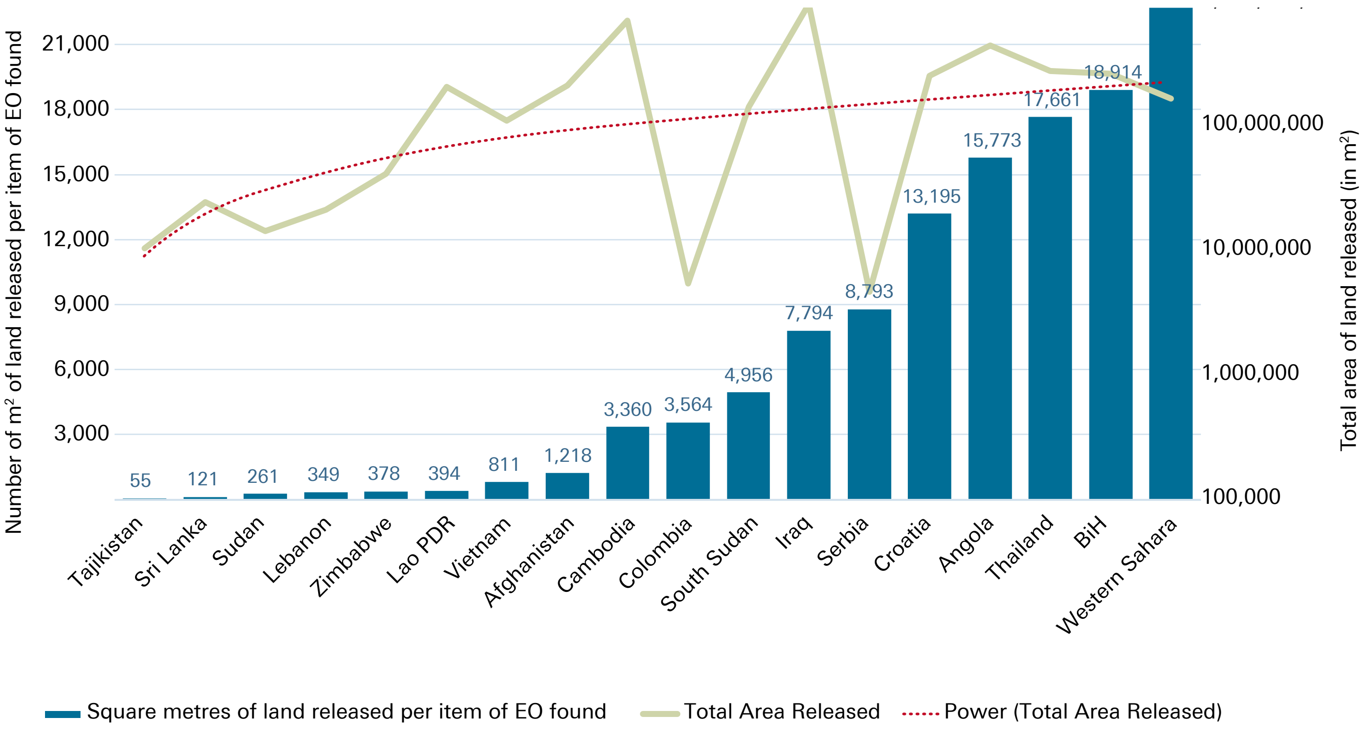


The study aimed to identify economies of scale in two areas. The first one was at the operational level to determine whether larger programmes, based on the total area of land declared as released each year, offered more targeted land release operations, as indicated by a lower area of land released per item of EO found. The second area was financial, to determine whether the cost of releasing land was lower in programmes that released the most land.

At the operational level, the results did not show any clear correlation when looking at releasing land. Programmes that released larger volumes of land did not appear to have more targeted operations than those releasing smaller total areas. This can be down to the fact that three different methods (cancellation, reduction and clearance) fall under the umbrella of land release. Areas that are cancelled are not expected to contain EO and are not searched to establish if any EO is actually present. Including cancelled areas in the released area will increase the KPI values for the number of square metres of land released per EO item found. Countries and territories that tend to clear most of the land they release, such as Vietnam, are more likely to score low in terms of square metres of land released per EO item found. Since very large releases of land typically involve significant cancellation, a relationship might exist between less accurate targeting of land release (as indicated by the number of square metres of land released per item of EO found) and larger volumes of land released. Although the trend line in Figure 27 might show a slight correlation, it is not clear enough to make any clear predictions.

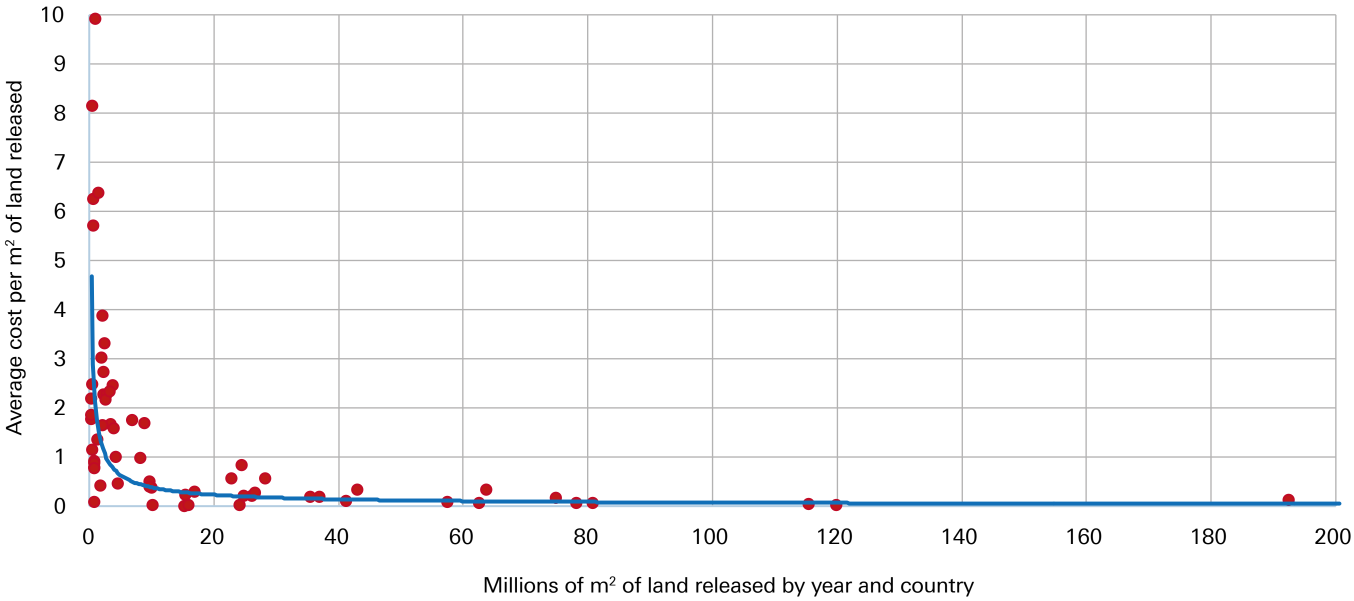
The study also examined financial economies of scale. Figure 28 considers the relationship between the total area of land released and the average cost per square metre of land released. It shows data points by year and country or territory, the total area of land released for each country or territory, and the average cost of each square metre of land released based on the total reported programme funding for that year. KPI distortions are likely as funds allocated in one year are used for operations in the next. Still, the general correlation appears clear. The more land is released, the less each square metre costs.

Figure 27: Number of square metres of land released per item of EO found compared to total area of land released in square metres (logarithmic scale).



Note: NMAA data was used for 11 territories, data from a UN agency for one territory, open-source data for six territories.

Figure 28: Financial economies of scale based on the average cost per square metre of land released in relation to the total area of land released, by year for each country or territory with available data.

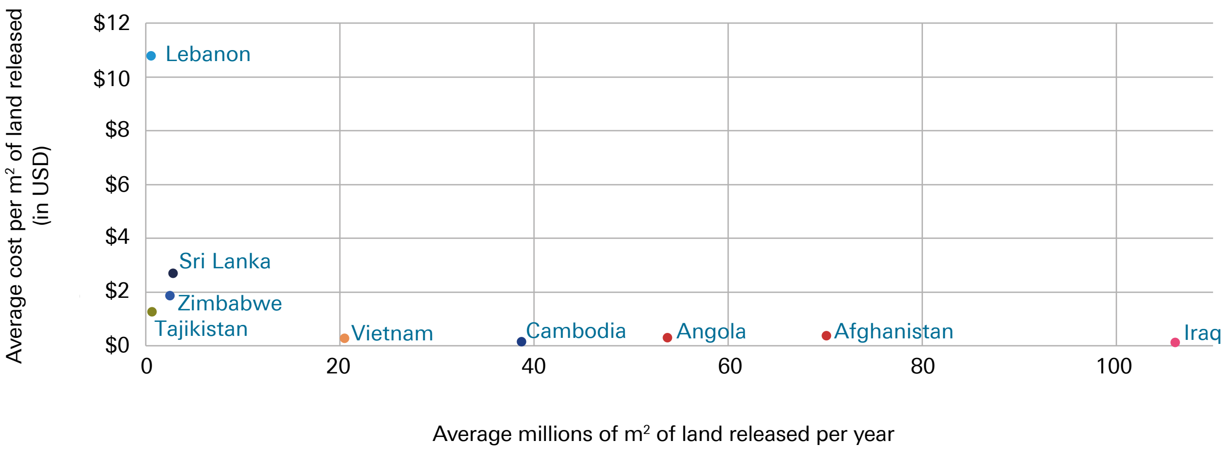


Note: The data set consists of 65 data points from five MAOs in 15 countries or territories (24 programmes in total).

As with so many aspects of KPIs related to land released, the level of cancellation has a significant influence on the results. The largest area of land released was associated with one year when cancellation was unusually extensive in Iraq. Results showing higher unit costs are associated with the release of less land, which focuses on the more costly activity of clearance. However, it is worth noting that countries and territories that actively conducted resurvey exercises between 2015 and 2019 have seen more cancellation than those that did not.

Figure 29 applies the same analysis across the whole 2015–2019 period by averaging each country's annual average values.[45] The higher underlying costs and greater focus on clearance in Lebanon is reflected in its position as one of the costliest countries for land release. Cambodia, on the other hand, has a similar ratio of land cleared to land released to Lebanon but releases much more land at a much lower cost. The country therefore sits midway between Vietnam and Angola in this analysis. The position of Iraq on the chart illustrates the influence of years with high reported cancellation volumes.

Figure 29: Average millions of square metres of land released per year compared to average cost per square metre of land released.



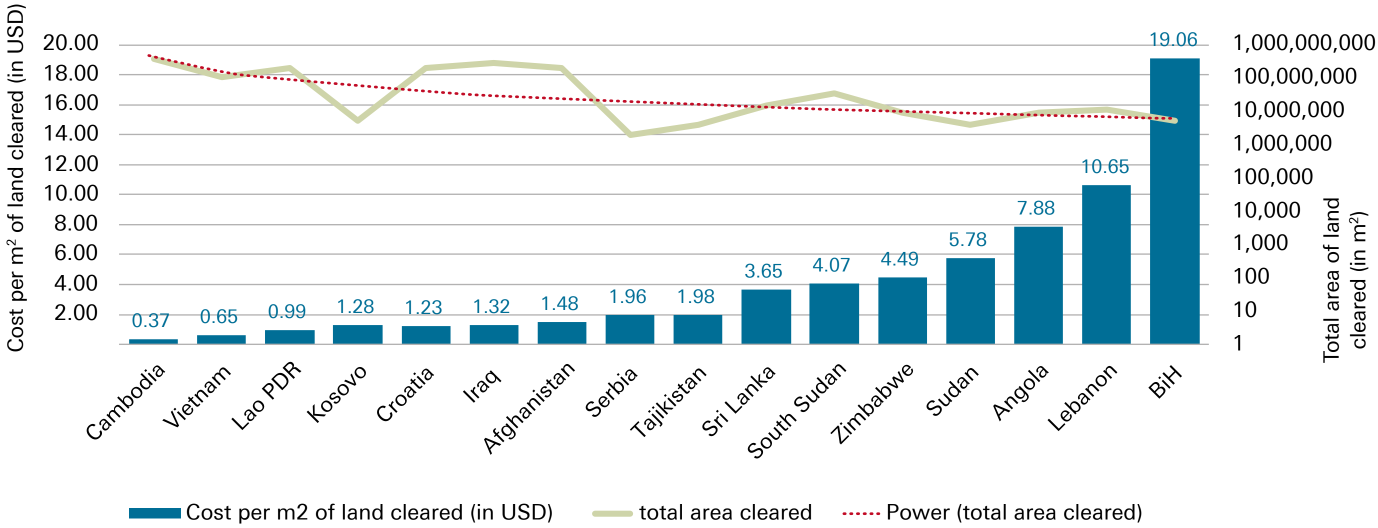
Note: Data from 5 MAOs in 11 countries (20 country programmes in total).

[45] Doing so addresses the issue that not all countries provided data for all the years covered by the study.

Analysing the amount of land cleared offers more opportunities to relate output and activity to input factors. Figure 30 presents the cost of clearance in comparison to the total area of land cleared. In this case, there is some evidence of economies of scale. Countries that cleared the largest areas of land, such as Cambodia or Croatia, also exhibited some of the lowest costs per square metre of land cleared. Conversely, countries that clear less land have higher costs per square metre of land cleared.

However, the correlation is not very strong as the cost of clearing land depends on many factors associated with terrain, vegetation, climate, as well as the tools and methods employed. Nevertheless, it is reasonable to expect that larger programmes would benefit from economies of scale, with the potential to share central costs more widely.

Figure 30: Cost per square metre of land cleared compared to total area of land cleared.



Note: For the total area of land cleared, NMAA data was used for eight countries and MAO data for eight countries.

ANNEX B: THE CONCEPT OF OPERATIONAL EFFICIENCY IN MINE ACTION

Efficiency is typically measured by comparing what is put into a process (people, time, money, resources, etc.) and what comes out of that process (land, information, etc.). This study explores the topic of operational efficiency in land release through two approaches. The first approach aims to describe and measure aspects of operational efficiency by identifying influencing factors, considering how they interact, and developing tools to better understand effects on efficiency. The second approach is to gather empirical data from operations and programmes around the world and analyse selected key performance indicators (KPIs).

Land release operations take place within specific national, local and organisational environments, which may involve contextual factors ranging from contamination patterns, and environmental considerations to broader social and political factors. These factors are beyond the control of mine action organisations. However, management decisions about how, when, and where to work, and what resources to deploy, can help mitigate these factors and determine the impact of physical factors, while maximising the use of resources. Understanding the roles of different factors and recognising how management decisions, practices and habits can significantly impact operational efficiency is essential to improve how the mine action sector operates public money to fulfil its professional and moral obligations to achieve as much as possible with the available resources.

The arithmetic of production and productivity

Efficiency can be measured at different levels within the land release system. One way is to take an overall perspective by comparing the total inputs to the total outputs. The cost per square metre of land released used in this study does this from a financial perspective. More detailed aspects of the system can also be analysed, like the number of square metres per deminer per hour, for example. Productive ratios, which compare the proportion of resources on site that deliver land to those that enable activity, are further examples of subsidiary KPIs. All these approaches quantify efficiency based on an input-to-output ratio.

To bring these different subordinate KPIs together under a common framework, this study makes use of a production equation:

PRODUCTION (P) = NUMBER OF PRODUCTIVE RESOURCES (N) X UNIT PRODUCTIVITY (U) X WORKING TIME (T)[46]

[46] There is no specific reference for this equation. It is a simple mathematical expression describing the relationship between the main elements of any productive process. There is consistency in the units used in that m^2 = a non-dimensional unit × m^2/time × time. The dimensions on both sides of the equation agree.

This framework recognises that the amount of output (or product) is determined by the number of productive resources (such as deminers) working, their productivity and their working time. During this study, aggregated, averaged information was used to generate KPIs at a national programme level. There was no opportunity to assess the performance of individual deminers. At this level of analysis, the general expression above is applicable.

A more detailed analysis of a single team at a specific site would capture the amount of time (T) each individual worked on a particular day, count the number of square metres they cleared in that time, calculate the rate at which they cleared this land (U), perform the same analysis for each deminer on site (up to the total number of deminers, N), and then sum the results to generate the overall figure (P) of land cleared on the site for that day.

The same approach can be applied to land released, but the relationship between individual resources and the total output is more difficult to analyse in detail. The amount of land released by a non-technical survey (NTS) team member through cancellation is determined by a combination of information availability, land release policy and personal confidence. Nevertheless, the same arithmetic structure can be applied to establish KPIs such as the number of square metres of land released per NTS surveyor.

In this study, production (P) refers to the output of land, whether cancelled, reduced or cleared. Other outputs are important in mine action and production efficiency could be analysed in the same way for other activities, such as the manufacture of prostheses for mine victims or the delivery of trained and qualified personnel by training establishments.

The number of productive resources (N) relates specifically to assets that can generate output, in this case, land. While the focus of this study has been on human deminers, other methods like animal detection systems (ADS), mechanical systems and NTS surveyors can also release land, either independently of other assets or together. Operations that use multiple assets can use the analysis methods in this study but they bring additional complications, as different asset types influence each other's performance characteristics.

When assessing operational efficiency, only productive resources can be counted under parameter N. Other resources on site perform important, even essential, functions (such as supervision, medical and logistical support and quality management) but they cannot generate output. At a manual clearance site, only deminers can generate output, making them the only productive resources on site.

Unit productivity (U) quantifies the rate at which a productive resource generates output. For a human deminer, this is the rate at which they clear ground. This ground may be subject to further inspection as part of internal quality control checks, but the basic rate of production is dictated by the rate at which the deminer can advance across the ground. Similar figures can be established for ADS and mechanical systems, as well as human deminers engaged in other types of searches, for example, during battle area clearance work, using large loop detectors, etc. In situations where one asset prepares the ground for another (for example, when a machine breaks up the ground or removes vegetation before manual or ADS assets search it), understanding the productivity of the preliminary asset is important. Such systems typically act as accelerators for the dedicated search asset. The productivity of manual deminers working in areas that have undergone mechanical preparation is expected to be higher (in square metres per deminer per hour) than that of deminers working in unprepared areas. This study focuses on a single productive asset type: deminers. More complicated models with more subsidiary KPIs can be developed for operations using multiple assets.

Working time (T) refers to the time spent generating output. The case study analysis extracted detailed data about when individual productive resources were or were not working, identifying rest periods, time spent on work that did not involve the generation of output (painting marking sticks, for example). Approximations and averages had to be used for the higher-level analysis used with most aggregated site-specific data provided by MAOs.

Various KPIs are available or can be developed to understand different aspects of the land release process. Table 8 shows the link between the KPIs in this study and the different elements of the production equation.

Table 8: Relationship between KPIs in this study and elements of the production equation.

Element of the production equation	KPI in this study	Notes
Production (P)	**Square metres of land released per item of EO found**	This KPI can be generated at different levels, from the whole site to individual teams, using aggregated results for an individual MAO, region, country, territory or even global results.
	Cost per square metre of land released	In this study, these KPIs were generated at the national level based on the availability of comparable data. More detailed financial audit processes could be investigate costs at the organisational or site level. This would require appropriate financial expertise and an agreement on the policies relating to the handling of amortisation, start-up costs, etc.
	Cost per square metre of land cleared	
	Cost per item of EO found	
Number of productive resources (N)	**Productive resource ratio**	In this study the KPI was generated at the level of individual sites, using data collected during case study field trips. The KPI can also be generated at the organisational level (comparing the total number of people in an organisation with the number of people who directly generate cleared or released land) or at the national level if suitable data is available.
	Productive cost ratio	This KPI can be applied at multiple levels depending on data availability. In this study, the KPI was generated specifically for human resources deployed on work sites. The costs of enabling resources were compared with the costs of productive personnel. The KPI could be extended to include costs associated with other assets, such as ADS and mechanical systems if suitable cost data is available.
Unit productivity (U)	**Square metres of land cleared per asset per hour**	To allow comparison between different operational units, MAOs or countries/territories, unit productivity needs to be normalised with clear base units. In this study, productivity is assessed per deminer per hour or day, where data is ratioed to a standard 6-hour day. Productivity indicators using units such as a team or a week should be avoided. Different organisations may apply different approaches to team size and length of the working week.
Working time (T)	**Productive time ratio**	Productive time ratios compare the amount of time a productive asset is available to generate output with the amount of time actually spent generating product. A deminer available on site for a 6-hour working day who spend 4 hours at work in a clearance lane would equate to a 75% productive time ratio. Time spent engaging in enabling activity on site, but away from a clearance lane, does not constitute productive working time within the bounds of operational efficiency analysis.
	Asset time per item of EO found	The amount of time each productive asset spends at work to find one item of EO is a higher-level indication of overall operational efficiency. The main objective of land release processes is to release safe land for follow-on use. However, it is widely accepted that time spent investigating land that does not in fact contain EO is undesirable at best. Much like the number of square metres of land released or cleared per item of EO found, this KPI provides insight into how closely targeted land release activity is. It is closely related to the cost per item of EO found.

Factors influencing operational efficiency

Using the terminology of the Cynefin framework, land release operations are complicated systems, in which expertise is required to identify and understand the causes and effects.[47] Indeed, intricate dynamics exist between a wide range of factors and influences, which can be environmental and circumstantial (and therefore beyond managers' control), or logistical and procedural (in this case, within the decision-making capacity of authorities and managers).

The diagram in Figure B.1 illustrates the influences of potentially significant factors that affect operational efficiency in mine action (based on the production equation). The diagram is not exhaustive and other aspects may be relevant depending on personal experience or prevailing circumstances and conditions in different countries or territories, and programmes.

Analysing such complex systems as land release operations can constantly bring new details into consideration. This study therefore only aims to highlight some of the most significant influences to help mine action managers and decision makers to recognise the implications of their decisions on operational efficiency.

Factors influencing land release outputs and objective setting (P)

Factors that influence the definition of areas that need to be processed (the 'production' requirement (P) in the production equation) include:

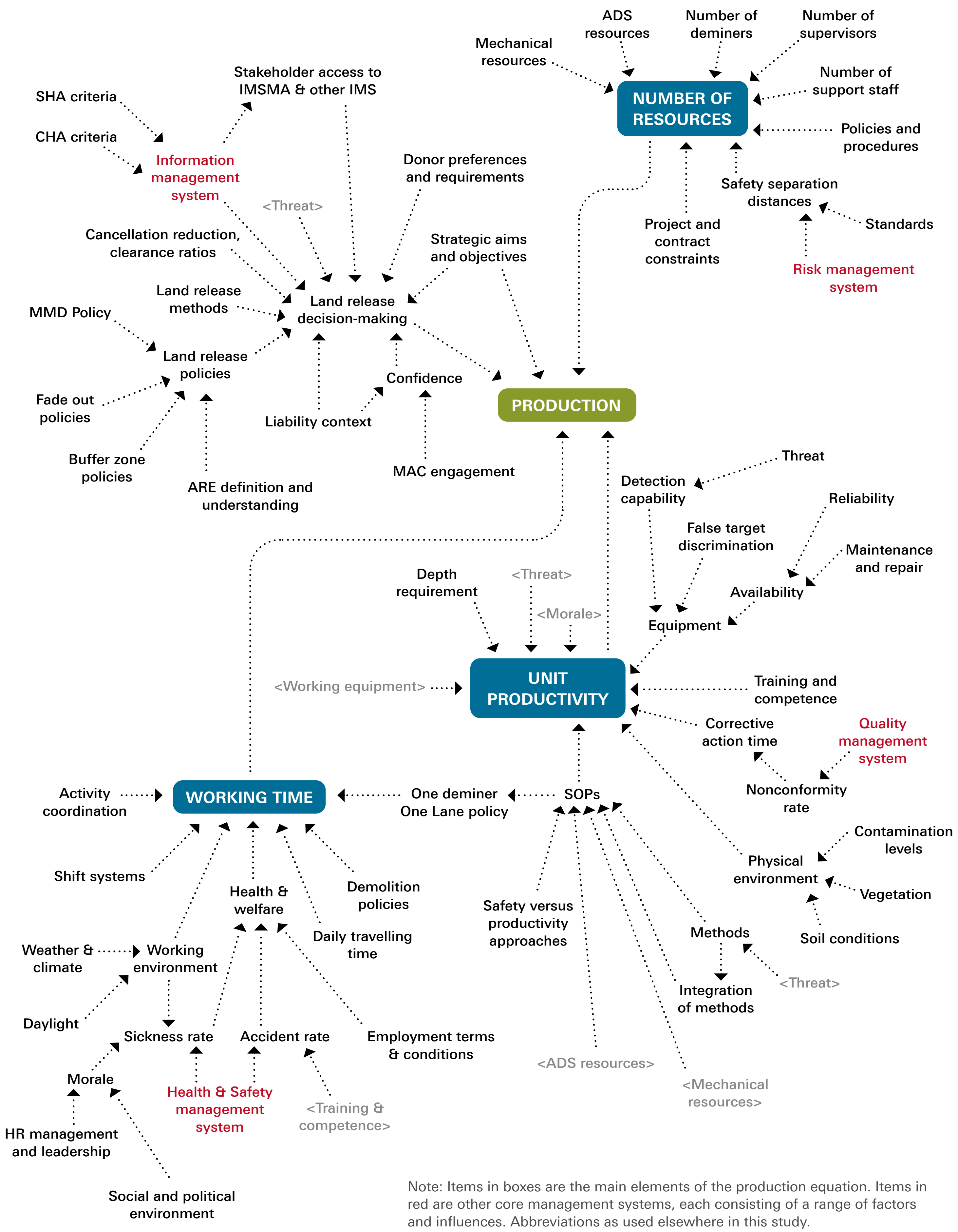
- **Strategic aims and objectives:** these influence the way in which a programme prioritises the different aspects of its operations.
- **The nature and distribution of the threat:** dense, regular, recorded landmine contamination will generally lead to more focused land release operations, whereas more distributed, irregular contamination, from older cluster munition remnants to general combat explosive remnants of war (ERW) residue and nuisance mining, is usually harder to localise.
- **Donor preferences and requirements:** for instance, the extent to which donors require evidence of operational efficiency and their definition of what constitutes evidence; the extent to which mine action stakeholders are incentivised to be efficient.
- **Comparisons between similar programmes:** perceptions of comparative performance based on higher-level reporting as part of treaty obligations and published sources.[48]
- **Clarity and understanding of all reasonable effort (ARE):** a critical part of establishing and maintaining the confidence of managers, monitors and authorities to take efficient and reliable land release decisions.[49]
- **The confidence of land release decision makers:** also influenced by the liability context and the extent to which the mine action centre, or other monitoring or supervisory body, engages with MAOs to observe, review and accept key land release decisions. This relates to the confidence of decision makers that they have access to relevant data, that their decisions are based on the available evidence, and that they will not unreasonably be held liable for problems at a later date. Programmes in which there is uncertainty about the risk of personal (or corporate) liability claims in the event of an adverse event after land release are likely to exhibit less efficient land release decision-making.
- **Land release policies:** such as those established for buffer zones, fade-outs, missing mine drills, etc. Small variations in distances associated with these policies can have huge implications when multiplied with the geometry of area.
- **Integration of different land release assets:** such as the 'information cost' of using some mechanical systems, where poor application of flails or tillers can turn a well-defined, ordered minefield into a poorly defined larger area of dispersed and distributed mine fragments. This can result in an increase in the production requirement, outweighing the supposed speed advantages on the right side of the equation, especially in terms of human unit productivity.
- **Access to information management (IM):** the ability of MAOs, monitors and authorities to access shared IM systems, most commonly (although not always) the Information Management System for Mine Action, is fundamental to their ability to engage in evidence-based decision-making.

[47] Using the meaning of 'complicated' associated with the Cynefin framework which contains domains: 'obvious' (sometimes also called clear or simple) in which cause and effect are known; 'complicated', in which cause and effect require expertise to identify and understand; 'complex', in which cause and effect can only be established in retrospect; and 'chaotic', in which cause and effect cannot be determined. See https://hbr.org/2007/11/a-leaders-framework-for-decision-making.

[48] In particular, the Landmine and Cluster Munition Monitor, http://www.the-monitor.org/en-gb/home.aspx.

[49] TNMA 07.11/03: All Reasonable Effort, provides further guidance.

Figure 31: Illustrative influence diagram for the main components of the production equation.



Note: Items in boxes are the main elements of the production equation. Items in red are other core management systems, each consisting of a range of factors and influences. Abbreviations as used elsewhere in this study.

Factors influencing resource deployment and availability (N)

In most mine action programmes, not all resources theoretically available to deliver products are fully employed on productive work at any given moment. Key factors that influence the proportion of potentially productive resource available to work include:

- **Leave rosters:** the number of individual leave days each year varies between countries or territories as do national holidays.

- **Sickness, compassionate leave and other non-scheduled time-off requirements:** reflecting a combination of aspects such as the working environment, the prevalence of illness, morale amongst workers and other aspects that may be included in employment terms and conditions.

- **Training:** time spent training is necessary to maintain the required levels of competence but reduces the availability of productive resources to engage in productive activity. Many programmes aim to conduct training during seasonal downtimes to minimise the impact on operational efficiency.

- **Equipment availability:** this includes 'downtime' for maintenance and repair or during seasonal stand downs; some productive activities may be impossible when critical equipment is unavailable. In some cases, a lack of equipment may not affect the number of productive resources (N) but could influence their individual productivity (U).

- **Safety separation distances:** these can influence the number of deminers that can work on a smaller work site. Policies may vary between MAOs and national programmes and are sometimes influenced by misconceptions about what IMAS 10.20 understands by: "To reduce the risk of injury to others at a worksite to a tolerable level, demining organisations shall determine appropriate working distances between individual deminers, machines or [Mine Detection Dogs] MDD and other staff on a demining worksite."[50] Furthermore, "Working distances shall be established based on a detailed and documented risk assessment taking into account the hazards associated with the site, the topography of the site and the protection provided to staff by equipment."[51] The application of excessive safety separations can negatively and unnecessarily impact operational efficiency by reducing the number of productive resources.

- **Contractual, logistical and managerial flexibility:** if potentially productive resources are unable to work at one site, the ability and willingness to redeploy them to other sites that have the capacity to absorb them becomes significant. During case study discussions, at least one operating organisation said that the way in which they are funded by a donor prevented them from moving individual deminers between work sites and teams, even if they wished to. The consequences of such administrative constraints can have a significant (negative) impact on operational efficiency.

- **One deminer one lane policies:** it is rare to find programmes that still require a second deminer to observe each deminer at work in a lane, other than during on-the-job training. Yet, a few programmes still have not moved away from this practice.[52] Having two deminers in one lane, one working and one observing, immediately cuts (N) by 50%, the number of productive resources at work, while continuing to incur the costs of these deminers even though they are not clearing land.

---

[50] IMAS 10.20: Demining Worksite Safety (first edition, October 2001; amendment 7, June 2013), section 5.3: Demining working distances.

[51] IMAS 10.20 Demining Worksite Safety (first edition, October 2001; amendment 7, June 2013), section 5.3.

[52] Having more than one deminer in a lane was common in the 1990s and continued in some programmes into the early 2000s. However, this practice is now generally accepted as being unacceptably inefficient and yielding no meaningful safety or quality benefit (the original justification for adopting the practice).

Factors influencing unit productivity (U)

- **The threat type:** the capability of detection equipment to discriminate against false targets is of clear and fundamental significance to technical survey and clearance productivity. Other threat aspects, such as the possible presence of trip wires, booby traps, minimum metal mines or improvised explosive devices, is also significant.

- **The availability of equipment:** if equipment is unavailable, stuck in a procurement process, taking a long time to repair, short of fuel or otherwise unavailable, then survey and clearance resources may have to fall back on slower methods or, even worse, be kept idle.

- **Training and competence:** these influence the rate at which deminers can safely progress using different methods and under different conditions.

- **Morale, motivation and health:** these topics are often related to wider questions of management methods, as well as the overall social, security and political context within which operations take place.

- **Accident rates:** the immediate effect of any serious incident or accident involving land release resources is often to reduce individual productivity, usually temporarily. Repeated accident rates are likely to have a longer-term impact on productivity.[53]

- **Find rates:** the frequency with which mines and other ERW are found may have an effect on productivity, in some cases accelerating it (perhaps through increased confidence in patterns of contamination or because a lack of finds may generate complacency about the presence of any threat). In very densely contaminated areas, operations can become dominated by repeated demolitions, also reducing output rates as less working time is spent covering ground.

- **Critical nonconformity rates:** areas that require reprocessing effectively reduce the productivity of a unit in direct proportion to the amount of ground that needs repeat processing.

- **Standard operating procedures and aspects:** such as one deminer one lane drills (or other more resource-intensive options).

- **Policy decisions:** such as imposing a 'metal free' requirement in areas where the combination of threat type and clearance methodology does not justify it.

- **Integration and coordination of different assets:** well-coordinated use of different assets, including people, ADS and mechanical systems can significantly increase productive output per critical resource (often the human deminer).

- **The local physical environment, including ground, vegetation, topography, weather, and wider seasonal effects:** aspects that are generally well understood in the mine action sector and for which various mitigation measures can be deployed, including mechanical vegetation clearance systems, ground preparation machinery, soil wetting, etc.

Factors influencing working time (T)

- **Local labour legislation** may impose constraints on mine action operations and the duration of the working day, as well as the relative number of days working and resting that a programme should adopt. It is rare for such legislation to impose limits on mine action operations that are more restrictive than the approaches already normally adopted by MAOs, but some additional costs may arise.

- **Time spent travelling to the work site** may impact on the number of working hours. Mine action managers typically consider the use of local camps or accommodation close to the work site to reduce the impact of travelling time, but long travelling distances and times are sometimes difficult to avoid. Any reduction in working hours to compensate for time spent travelling has a direct and proportional effect on the (T) element in the production equation – a 10% reduction in working time leads to a 10% reduction in the production figure.

- **The health, welfare and morale** of workers may also be reflected in absence rates.

- **Policies on the frequency and management of demolition** can have a significant impact on productive working time. Some programmes require demolitions to be carried out on all items of EO found on the day they are discovered. Others allow items of EO to be marked and destroyed in bulk as and when the number of objects justifies it. When the demolition is conducted, and which resources are used, further influences the situation.

- **Stakeholder expectations:** as with other aspects of operational efficiency, the expectations and requirements of stakeholders, such as donors, customers and the senior management of MAOs, determine to a great extent the level of effort put into trying to maintain and improve operational efficiency.

---

[53] Noting that safety is an overriding objective of mine action operations. The pursuit of operational efficiency improvements should never be seen as a justification for a reduced focus on safety.

- **Coordination of activity** affects working time as well as unit productivity. Poor coordination of assets can lead to productive resources standing idle while they wait for other activities to be completed.

- **Social, security, and political environment** can lead to interruptions to working time as a result of security incidents, industrial unrest and other events.

- **Environmental factors:** weather can temporarily stop work, such as when high winds or rain prevent ADS from working, or because of more serious events such as earthquakes, landslides and flooding. In some countries and territories, extended stand-down periods may be built into the annual work plan. Tidal cycles are often a significant factor when land release operations take place at coastal sites. Mine action resources are often redeployed to provide civil support during emergency periods (as they did in many cases during the COVID-19 pandemic). While such support is admirable, it will reduce working time (T).

- **Daylight:** particularly significant at sites at higher latitudes when daylight periods may be shorter, or in areas with high temperatures when work often starts as early as possible. When combined with factors such as tidal cycles, daylight can become a significant constraint to potential working time. In some types of activity, especially operations relying primarily on mechanical systems such as sifters, floodlighting may be an acceptable means of controlling the impact of daylight on working time.

- **Use of shift systems:** under some circumstances, it may be possible to operate shift systems with different groups of land release assets working on the same site at different times of day to maximise the amount of working time (T) delivered in any 24-hour period.

- **Site starting and stopping routines:** when extra (non-productive) time may be spent preparing the site for work or when, on completion of operations, activities like environmental remediation use asset time for non-productive purposes.

- **Public safety aspects:** such as when clearance operations take place at a site with a public road running through it, in close proximity to civil aviation routes or to comply with agreements with local authorities to minimise disturbance to the nearby population.

ANNEX C: METHODOLOGY

Purposive sampling was used for this study, meaning that data was requested from targeted operators and country programmes to reflect the reality of data collection in mine action. The study focussed on the period between 2015 and 2019 to allow for a wide range of data while avoiding to account for the consequences of the COVID-19 pandemic on land release operations.

One recognised challenge of the mine action sector is the standardisation of the collection, recording and reporting processes of key operational data. Annex B to *IMAS 05.10, Information management for mine action*, sets out important minimum requirements, including measurement units, for a range of data fields within a typical mine action information management system. However, it does not yet specify detailed operational key performance indicators (KPIs). As a result, not all organisations count and report underlying data in the same way, creating challenges for studies like the present one.

In light of these challenges, the number of indicators included in the calculations was narrowed down to those for which essential data was available. These indicators were:

- Number of items of EO found, broken down by type;
- Square metres of land released and cleared;
- Deminer days;
- Funding for land release.

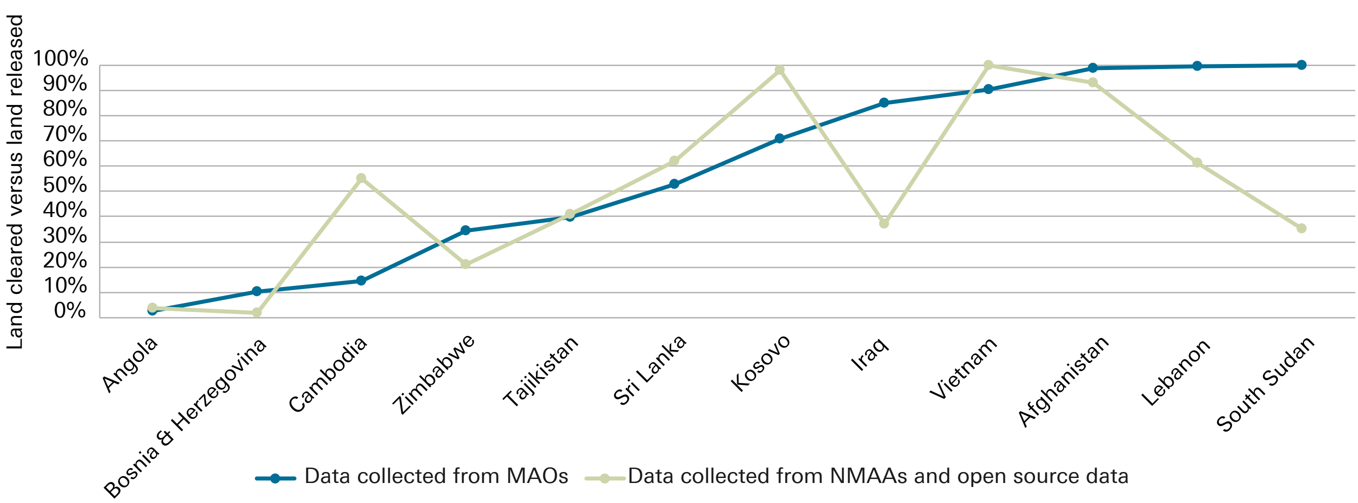
All operators collected information on the number of items of EO found at each site, disaggregated by type. Data on the number of square metres of land released and cleared was also available.

While no universal agreement has yet been achieved, it is important to note that, after extensive discussions, greater consensus has been reached regarding uncertain identification of land released as cancelled, reduced or cleared; for example, whether land searched during technical survey is treated as clearance or included in an all-up figure for reduced land. This study collected data from 2015 to 2019, when there was still more divergence in how different organisations treated these questions. As a result, some inconsistencies are likely in how data was reported. However, given the global scale of this analysis, they are unlikely to have much influence on the overall results.

Overall, deminer days were identified for only 64 per cent of the cleared tasks. Identifying the total number of hours worked on site per day would have allowed for more detailed analysis but this data was very rarely collected. Consequently, the figures were added to the data sets when it was possible to estimate the number of deminer days retrospectively through conversations with operators.

Finally, cost data was difficult to obtain and even more difficult to verify. The study therefore focussed on the total funding received by each country for land release operations, as it was the most widely shared indicator and the least influenced by subjective counting. Calculated costs may be slightly higher as a consequence, since data could not be disaggregated and excluded costs not directly impacting the related KPI. It is thus not possible to understand the circumstances affecting cost between countries. Although these limitations must be taken into account, the cost-related KPIs may still be considered as indications of cost in the land release process.

Figure 32: Variations between NMAA and open-source data, and MAO data for the proportion of land cleared and released.



All data sets underwent rigorous data quality check in terms of completeness, consistency and logic. Continuous discussion with the relevant actors ensured clarity and consistency in the data. When possible, data points were triangulated between data received from NMAAs, MAO and donors, and open-source data. As shown in Figure 32, the ratio of land cleared to land released varied significantly between MAO and NMAA/open-source data. Open-source data was used when NMAA data was not available. NMAA data was prioritised as it provides an overview at the national level. When NMAA data was not available, MAO or donor data was used. Open-source data was used as a last resort.

Figure 33 shows a concrete application of the logic outlined above. The blue lines trace the breadth of results per country or territory based on all available sources and the red squares pinpoint the values used in the analysis. While the data received from different sources did not vary much in countries such as Angola, Iraq or Vietnam, it varied greatly in countries such as the Lao PDR and Sri Lanka. Three measures helped mitigate these differences: information requests to stakeholders, triangulation among all data sources and the application of a consistent methodology for all countries and territories. Challenges linked to collecting and analysing data are inherent to conducting research in the mine action sector. As stated throughout this study, mine action managers should be refrain from using any of the KPI data set out as the basis for contractual terms or other fixed parameters.

Figure 33: **Variation in the cost per square metre of land released, using NMAA, MAO and open-source data.**

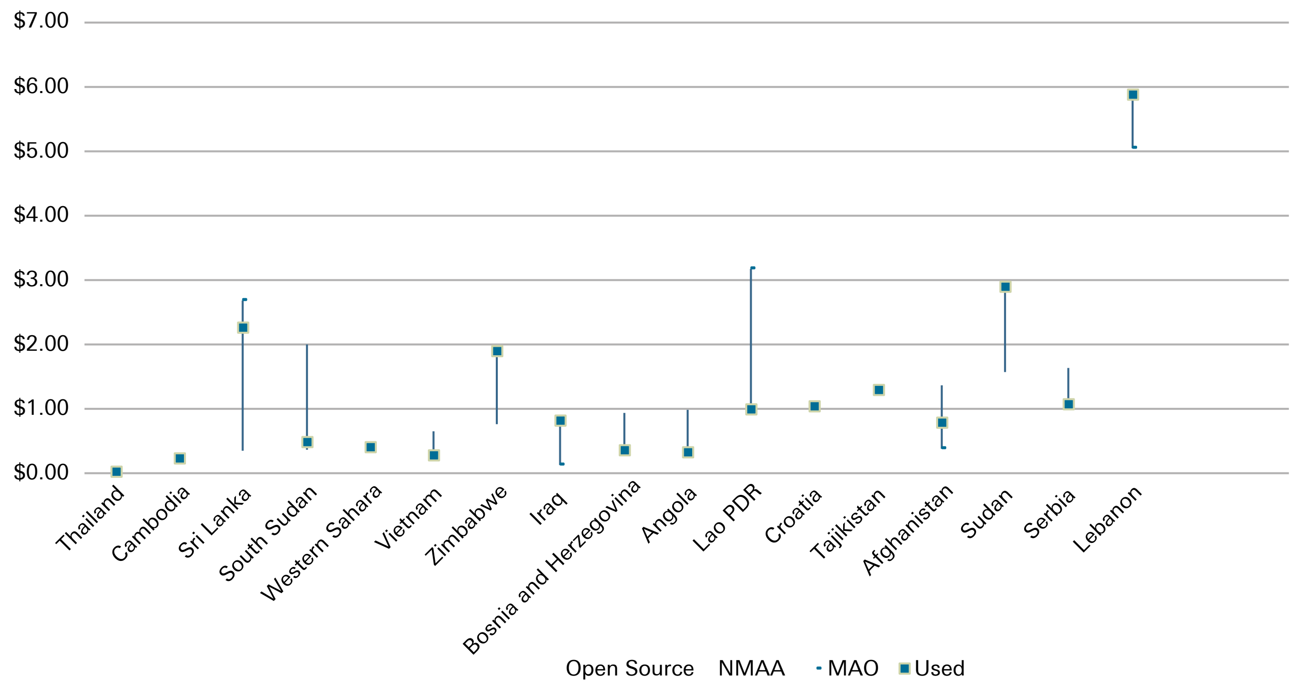


Table 9: Summary of KPIs, data sources, inclusion criteria and data volumes used in the study

Outputs/ production

KPI: Square metres of land released/cleared per item of EO found			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 1: Average number of square metres of land released per item of explosive ordnance found	▸ NMAA ▸ Open source	When provided, NMAA data was favoured over open-source data.	▸ 15 NMAAs ▸ 9 open source
Figure 2: Average number of square metres of released land per explosive ordnance item found, in comparison to the age of the national programme in years	▸ NMAA ▸ Open source ▸ Landmine and Cluster Munition Monitor country reports 2021	When provided, NMAA data was favoured over open-source data. The age of programme was calculated using the start date for mine action operations in country provided by the Landmine and Cluster Munition Monitor country reports 2021.	▸ 15 NMAAs ▸ 9 open source
Figure 3: Average number of square metres of land cleared per item of explosive ordnance found	▸ NMAA ▸ Open source	When provided, NMAA data was favoured over open-source data. Senegal was excluded from the analysis as it was an outlier (14,931 square metres of land cleared per item of EO found).	▸ 10 NMAAs ▸ 8 open source
Figure 4: Perception of how well-defined all reasonable effort is in comparison to the number of square metres of land cleared per item of explosive ordnance found	▸ NMAA ▸ Open source ▸ MAO SurveyMonkey	When provided, NMAA data was favoured over open-source data. A SurveyMonkey questionnaire asked operators to score how well-defined and applied (1–5) all reasonable effort (ARE) was in their country of operations. These scores were then averaged for each country.	▸ 5 NMAAs ▸ 6 open source ▸ 6 operators across 11 countries (24 country programmes)
Figure 5: Number of square metres of land cleared per mine found (anti-personnel and/or anti-vehicle)	▸ MAO site data	Exclusion criteria: 1. All sites with no mines found or no land cleared were excluded. 2. Except for one outlier, the maximum number of mines found at a site in Cambodia was 500 mines. To compare all three trend line sites with more than 500 mines, mines in the Lebanon and global data set were excluded. This ensures that the data range for all three trend lines is the same. 3. All tasks where less than 75% of the items of EO found were mines were excluded from the analysis.	▸ 2,286 sites (global) ▸ 439 sites (Cambodia) ▸ 74 sites (Lebanon) Note: Sites in Lebanon and Cambodia are included in the global trend line.

Outputs/ production

KPI: Square metres of land released/cleared per item of EO found			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 6: Average number of square metres of land cleared per cluster munition remnant found	MAO site data	Exclusion criteria: 1. All sites with no CMRs found or no land cleared were excluded. 2. Except for two outliers (one in each country), which were excluded from the analysis, the maximum number of CMRs found per task was just under 410 for both countries. 3. Two tasks (one in each country) were excluded as an equal or greater number of mines to CMR ratio was apparent.	30 sites (Lebanon) 50 sites (Cambodia)
Figure 7: Percentage of sites by country where no explosive ordnance items were found	MAO site data	Sites where at least 75% of released land was subject to clearance to avoid inclusion of sites where TS was the primary response (4,000 out of the total of 10,122 tasks). A total of 26% of included tasks showed zero items of EO found. Charted countries are those for which more than 10 tasks meeting the inclusion criteria were reported – 3,692 data points.	3,692 sites

KPI: Ratio of land cleared to land released			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 8: Ratio of land cleared to land released	NMAA Open source Donor	When provided, NMAA data was favoured, then donor data and finally open-source data was used when no other data source could be used.	9 NMAAs 10 open source 1 donor
Table 1: Summary of land release KPIs for Afghanistan from 2009 to 2019	GICHD assessment (2019)	As detailed in the source study.	As detailed in the source study

Number of resources

KPI: Productive resource ratios			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 9: KPIs in Afghanistan by year (2015–2018)	DMAC	Data was collected from DMAC during an in-country assessment in 2019.	N/A
Figure 10: Effect of different team management policies on the productive resource ratio	Case study	Data was collected in country through daily diaries and interviews with operators.	Data collected from 3 MAOs in Lebanon
Figure 11: Productive resource ratio at constrained sites	Case study	Data was collected in country through daily diaries and interviews with operators.	Data collected from 3 MAOs in Lebanon
Figure 12: Productive resource ratio at one clearance site in Lebanon over a period of 55 days	Case study	Data was collected in country through daily diaries and interviews with operators.	One site consisting of 55 site days

Unit productivity

KPI: Square metres of land cleared or released per asset per day			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 13: Frequency of occurrence of square metres cleared per deminer per day	MAO site data	All sites with no deminer days recorded or no m^2 cleared were excluded. Outliers were identified and further discussions were conducted with MAOs to understand why these tasks were outliers.	3,117 sites
Figure 14: Number of square metres of land cleared per deminer per hour at a single clearance site in Lebanon over 55 days.	Case study	Data was collected in country through daily diaries and interviews with operators.	One site consisting of 55 site days
Figure 15: Relative performance of men and women deminers.	Gender & operational efficiency study	Data from teams with no more than a 30%/70% gender mix; teams had to provide at least 20 daily values on average per deminer.	7,575 data points

Working time

KPI: Productive time ratios			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 16: Proportion of deminer hours spent on productive work (generating output) at one example site in Lebanon	Case study	Data was collected in country through daily diaries and interviews with operators.	One site consisting of 55 site days

Working time

KPI: Asset time per explosive ordnance			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 17: Frequency of occurrence of deminer days per item of explosive ordnance found	MAO site data	Exclusion criteria: 1. All sites with no mines found or no land cleared were excluded. 2. All tasks where 75% of the items of EO found were mines (or less) were excluded. Outliers were identified and further discussions were conducted with MAOs to understand why these tasks were outliers.	1,681 sites
Table 2: Summary of proportion of cumulative deminer days per mine	MAO site data	As for Figure 16.	1,681 sites
Figure 18: Profile of the number of mines found each working day, over 71 days, at a site in the Falkland Islands/Malvinas	Falkland Islands daily diaries	Data was collected through daily diaries.	1 site over 71 site days

Cost analysis

KPI: Cost per square metre of land released			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 19: Average cost in USD per square metre of land released	NMAA MAO SurveyMonkey Open source	Cost data was triangulated using all available data sources. NMAA and MAO SurveyMonkey data was favoured.	6 NMAAs 5 MAOs SurveyMonkey 6 open source
Table 3: Deminer and supervisor salaries compared with minimum and average wages in Cambodia and Lebanon	Case study ILO SurveyMonkey	Data from listed sources (case studies and ILO) relevant to Cambodia and Lebanon.	N/A
Figure 20: Cost per square metres of land released, in USD, as a proportion of per capita GDP.	NMAA MAO SurveyMonkey Open source The World Bank	Cost data was triangulated using all available data sources. NMAA and MAO SurveyMonkey data was favoured. GDP data was extracted from the World Bank (www.data.worldbank.org).	6 NMAAs 5 MAOs SurveyMonkey 6 open source GDP data extracted for all 20 countries

Cost analysis

KPI: Cost per square metre of land cleared			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 21: Cost per square metre of land cleared, in USD	NMAA MAO SurveyMonkey Donor Open source	Cost data was triangulated using all available data sources. NMAA and MAO SurveyMonkey data was favoured.	7 NMAAs 5 MAOs SurveyMonkey 1 donor 4 open source
Figure 22: Cost per square metre of land cleared in comparison to the average deminer salary (in USD)	NMAA MAO SurveyMonkey Open source Case study	Cost data was triangulated using all available data sources. NMAA and MAO SurveyMonkey data was favoured. Deminer salaries were provided by operators. Case study data was also used to determine average deminer salary in Cambodia and Lebanon.	7 NMAAs 5 MAOs SurveyMonkey 1 donor 4 open source 7 operators from 11 countries provided deminer salaries (total of 23 country programmes)
Figure 23: KPIs in Croatia, by year	CROMAC	Data was collected from CROMAC during an in-country assessment.	N/A
Table 4: Summary of study KPIs for Croatia during the period 2015–2019	CROMAC	Data relevant to Croatia used elsewhere in this study.	N/A

KPI: Cost per item of explosive ordnance found			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 24: Cost per item of explosive ordnance found, in USD	NMAA MAO SurveyMonkey Open source	Cost data was triangulated using all available data sources. NMAA and MAO SurveyMonkey data was favoured.	7 NMAAs 2 MAOs SurveyMonkey 8 open source
Table 5: Comparison of KPIs related to cost and area for Cambodia and Lebanon	Case study	Combination of case study data and data from elsewhere in this study.	N/A
Table 6: Cost data in Colombia compared to global cost averages	Study data	Data extracted from other sections of this study.	N/A
Figure 25: KPIs in Colombia, by year	NMAA	Summary charts for a number of KPIs used elsewhere in this study.	N/A

Cost analysis

KPI: Productive cost ratios			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 26: Average proportional costs relative to a deminer's salary for MAOs in Lebanon	‣ Case study	Data was collected in country through daily diaries and interviews with operators.	‣ 3 MAOs
Table 7: Illustrative comparison of key cost data and ratios for Cambodia and Lebanon	‣ Case study ‣ NMAA ‣ MAO SurveyMonkey	Data was analysed from NMAA and MAO SurveyMonkey data. Additional information was extracted from case study data (daily diaries and interviews with operators).	‣ Cambodia (1 NMAA, 1 donor & 5 operators) ‣ Lebanon (1 NMAA & 4 operators)

KPI: Economies of scale			
Figure number	**Data source**	**Inclusion criteria**	**Number of data points**
Figure 27: Number of square metres of land released per item of EO found compared to total area of land released	‣ NMAA ‣ Open source	When provided, NMAA data was favoured over open-source data. Senegal was excluded from the analysis as it was an outlier (14,931 m^2 cleared per EO item found).	‣ 11 NMAAs ‣ 1 UN agency ‣ 6 open source
Figure 28: Financial economies of scale based on the average cost per square metre of land released in relation to the total area of land released, by year for each country with available data.	‣ MAO SurveyMonkey	Included in the analysis are all years (2015–2019) where data was available for a country.	‣ 65 data points corresponding to data from 5 operators from 15 countries (24 country programmes)
Figure 29: Average millions of square metres of land released per year compared to average cost per square metre of land released	‣ MAO SurveyMonkey	Countries where data was available for every single year (2015–2019) were included in the analysis.	‣ 5 operators from 11 countries (20 country programmes)
Figure 30: Cost per square metre of land cleared compared to total area of land cleared	‣ NMAA ‣ MAO SurveyMonkey	Cost data was triangulated using all available data sources. NMAA and MAO SurveyMonkey data was favoured.	‣ 8 NMAAs ‣ 8 MAO s

ANNEX D: FURTHER READING AND SOURCES

The bibliography provided here includes some publications that focus on specific operational efficiency aspects relevant to this study. It also includes a wider range of documents considering the effectiveness as well as efficiency of mine action operations.

History of breakthroughs in mine action programmes

Several books relate the long history of mine action and are still relevant for researchers interested in the genesis of the mine action sector and in the evolution of thinking within the sector regarding development of key performance indicators and metrics for evaluating the success of mine action interventions.

- Davies, Paul. War of the Mines: Cambodia, Landmines and the Impoverishment of a Nation. 1994.
  Davies's early history of the mine action sector in Cambodia includes the still relevant discussion of prioritisation and resource allocation issues, as well as an examination of the inadvertent roots of the Cambodian Mine Action Centre (CMAC) in the UN Transitional Authority in Cambodia.

- Maslen, Stuart. Mine Action After Diana: Progress in the Struggle Against Landmines. 2004.
  Maslen's book builds on discussions of metrics in the humanitarian mine action sector and includes a frank discussion about the failure of output-based metrics to account for the enhanced sense of security which mine action can produce and frameworks for the conduct of mine action interventions. For example, despite the emphasis of the 'Bad Honnef Framework' on the participation of mine-affected communities, the mine action sector has not always incorporated contributions from 'village deminers' in planning and prioritisation processes.

- McGrath, Rae. Landmines: Legacy of Conflict, a Manual for Development Workers.1994.
  Written with development workers (not mine action specialists) as a target audience, this early text discusses some of the questions which are still unanswered in mine action. McGrath is clear that even with contamination, residents of contaminated areas do not seriously consider abandoning their land, and they will continue to enter contaminated areas out of economic necessity.

- McGrath, Rae, and Eric Stove. Landmines in Cambodia: The Coward's War. 1991.
  One of the earliest books published about landmines, as mine action was in the nascent stages of sectoral development. This book helps establish the history of the mine action sector and is notable for discussion of extremely optimistic time frames (four to five months) required to eradicate landmines in Cambodia.

- Roberts, Shawn and Jody Williams. After the Guns Fall Silent: The Enduring Legacy of Landmines. 1995.
  Roberts and Williams examine the human, social, economic and environmental cost of anti-personnel landmines, with case studies provided for countries including Afghanistan, Bosnia and Herzegovina, and Croatia. It includes a discussion of the costs of clearance, local resilience and risk reduction strategies, as well as the use of confidence-building measures by humanitarian mine action organisations to enhance community trust in released land products, even when no landmines are found on land suspected to be hazardous.

Efficiency

- AVS. Comparative Trials of Manual Mine Clearance Techniques. 2004.
  This report outlines the results of comparative trials of manual demining techniques in a controlled environment, in order to assess their relative efficiency in terms of speed and safety, as well as a series of interviews with deminers regarding their opinions about different manual demining techniques.

- Bach, Håvard. A Study of Mechanical Application in Demining. GICHD. 2004.
  Drawing on recent research, this study argues for a wider application of mechanical demining assets, including as the primary 'clearance' system (written before the development of land release methodologies). The study also includes a comparison of 15 mine action programmes across different countries, examining the percentage of supposedly hazardous ground which actually contained hazardous devices.

- Bach, Håvard. "Scalable Technical Survey for Improved Land-release Rates". Journal of Conventional Weapons Destruction 18 (2014):5.
  To reduce costly deployment of mine action resources, this study argues for a more holistic use of technical survey alongside other land release methods, rather than considering technical survey an isolated activity.

- Filippino, Eric and Ted Paterson. "Mine Action Lessons and Challenges: Is Mine Action Making a Difference … or Avoiding the Question?". Journal of Mine Action 9, no. 1, Article 11. 2005.
  Filippino and Paterson explore whether mine action has made a difference in its first 15 years of activity. They discuss the selection of minefields for clearance and the relationship between the ease of clearance and the ability to report falling operational costs.

- GICHD. A Study of Manual Mine Clearance (Books 1-5). 2005.
  This five-volume study includes a history of manual mine clearance, a discussion of the management of manual mine clearance programmes, a series of case studies and experimental trials regarding operational systems of manual mine clearance, strategies for assessing and managing the risk of mined areas, and discussion of the costs of manual mine clearance.

- GICHD. Management of Residual Explosive Remnants of War in Cambodia. 2018.
  This study examines Cambodia's explosive remnants of war risk management policy, presented as an effective and efficient risk management framework, including for managing risks connected to infrastructure projects, as Cambodia begins to consider winding down its large-scale mine action programmes.

- Lark, Raphaela, David Hewitson and Dominic Wolsey. "Gender and Operational Efficiency". Journal of Conventional Weapons Destruction 26, vol. 1, Article 7 (2022).
  The article investigates whether there are any differences in the performance of men and women in practical field technical survey and clearance roles and in their availability to work. It finds no evidence of any significant difference in either case.

- MAG. Efficiency, Effectiveness, and Impact in Mine Action. 2015.
  This Mines Advisory Group study points out that the use of mechanical clearance assets and mine detection dog teams can actually decrease efficiency if not targeted properly. It also comments that actual execution of the Information Management System for Mine Action has been primarily about data collection, not project design, delivery or improvement

- Poling, Alan et al. "Using Trained Pouched Rats to Detect Land Mines: Another Victory for Operant Conditioning". Journal of Applied Behavior Analysis 44, vol. 2 (2011):351–355.
  An early look at the use of giant African pouched rats as explosive ordnance detection animals, based on trials in Mozambique. The study includes specific examination of the rats' rates for false alarms and comparison to IMAS 09.40 Animal detection systems – Principles, Requirements and Guidelines.

Economic analysis

There have been several formal cost–benefit analyses of mine action interventions throughout the development of the mine action sector. However, methodologies have differed, especially regarding the selection of discount rates and inclusion of in-kind contributions, as well as accounting for additional costs, including salaries for expatriate technical advisers and in-kind contributions of capital equipment.

Additionally, in the past few years various proxy indicators for the effectiveness of mine action interventions have been proposed by academic researchers using econometric analysis, including night-time luminosity data.

- Byrd, William and Bjorn Gildestad. Socio-Economic Impact of Mine Action in Afghanistan: A Cost-Benefit Analysis. 2001.
  This study found considerable net socio-economic benefits from the mine clearance activities of the Mine Action Programme of Afghanistan, with specific benefit for irrigation systems, roads and highly productive agricultural land.

- Cameron, Michael P., et al. Value of Statistical Life and Cost-Benefit Evaluations of Landmine Clearance in Cambodia. Environment and Development Economics 15, no. 4 (2008).
  This study updates the methodologies used in some cost–benefit analyses of mine action interventions by abandoning the 'foregone income' approach and estimating the value of a statistical life using a contingent valuation survey, after which mine action interventions appear to be much better 'value for money'.

- Chiovelli, Giorgio, et al. Landmines and Spatial Development. NBER Working Paper 24758. 2018.
  Using sophisticated analysis and a detailed compilation of several data sets from Mozambique, the authors reveal that clearance of transportation networks, trade hubs, and populous areas are linked to proxy indicators of economic development, suggesting that economic gains from clearance might have been even more profound.

- Elliot, Gareth and Geoff Harris. "A cost-benefit analysis of landmine clearance in Mozambique". Development Southern Africa 18, no. 5 (2010): 625–633.
  Like Geoff Harris's 2000 cost–benefit analysis of landmine clearance in Cambodia, this study estimates a very large negative net present value of mine action interventions, while acknowledging that benefits from clearance include lives saved, injuries and medical costs avoided, and higher agricultural output.

- Harris, Geoff. "The economics of landmine clearance: case study of Cambodia".
  Journal of International Development 12, no. 2 (2000): 219–225. This early cost–benefit analysis found that the cost of mine action interventions far outweighs the benefits, using calculations derived from estimates of foregone wages for Cambodian agricultural workers following landmine and explosive ordnance (explosive ordnance) accidents. The methodology was sharply criticised in a follow-up analysis by Ted Paterson.

- Harris, Geoff. "The economics of landmine clearance in Afghanistan". Disasters 26, no. 1 (2002): 49–54.
  Unlike Harris's analyses of Cambodia and Mozambique, this study finds very high net present value from mine action interventions, and postulates that the inclusion of refugee resettlement and the clearance of transport networks in the Afghan model may have had an influence on the analysis.

- Gildestad, Bjorn. "Cost-Benefit Analysis of Mine Clearance Operations in Cambodia". Global CWD Repository 1155 (2005).
  This thorough study is stark in its assessment that casualties will continue indefinitely in Cambodia at a modest rate, and laments that cost–benefit analyses of mine action interventions are complicated because field team composition, techniques and equipment are not standardised across operators, and military clearance is often accounted for very differently.

- Keeley, Robert. The economics of landmine clearance. 2006.
  Robert Keeley's thesis discusses a host of issues related to mine action effectiveness, efficiency, and impact, and includes frameworks and strategies for analysing the allocation of scarce mine action resources at all levels, from the donor-strategic level to the deminer-technical level.

- Mansfield, Ian. A Business Case for Mine Action Completion. GICHD. 2012.
  Mansfield argues that clearing high priority, high impact areas is a good investment, but that other forms of clearance are less justifiable from a 'business perspective', but also discusses positive externalities from clearance of low or no-impact areas, such as progress toward Mine Ban Treaty obligations, the peacebuilding benefits of a peace dividend, and the elimination of explosives for insurgents.

- Mine Clearance Planning Agency. Socio-Economic Impact Study of Landmines and Mine Action Operations in Afghanistan. 1999.
  One of the first socio-economic studies on the impacts of mine action, this research attempts to quantify the negative impact of landmine contamination on afflicted communities, as well as the positive effects from mine action interventions.

- O'Reilly, Sheelagh, et al. Meta Evaluation of Mine Action and Development. IOD PARC. 2012.
  This meta evaluation of mine action interventions determines that the linkages between mine action and development are not well understood, that interpretations of evaluation criteria differ between the mine action and development sectors, and that prioritisation of mine action tasks must be linked to land use planning and governance/anti-corruption programming.

Triangulation

- Bottomley, Ruth. A Study on the Dramatic Decrease of Mine/UXO Casualties in 2006 in Cambodia. 2007.
  In this short study conducted on behalf of the Cambodian Mine Action and Victim Assistance Authority, Bottomley examines the approximately 50% reduction in landmine and explosive ordnance accidents between 2005 and 2006 and suggests that increased agricultural yields may have contributed to the drop in the casualty rate. Yet, she concludes that there is no single explanation responsible for the dramatic reduction in the casualty rate.

- Durham, Mary. Examining who benefits, in what ways, and in what contexts from mine action in the Lao People's Democratic Republic and Kurdish Iraq. 2012.
  Based on research in the Lao PDR and Kurdish Iraq, Durham's thesis examines how mine action contributes to post-conflict recovery, especially though the creation of a livelihood asset scale capturing self-reported changes in household assets after mine action interventions.

- GICHD and UNDP. A Study of Socio-Economic Approaches to Mine Action. 2001.
  This report highlights the non-availability of costing information of mine action interventions, citing a figure of two incomplete submissions following 20 requests for costing information from mine action operators. Evaluations of mine action interventions almost two decades later cite the same lack of accurate costing information as a limitation.

- Horwood, Christopher. "Ideological and analytical foundations of mine action: human rights and community impact". Third World Quarterly 24, no. 4 (2010): 939–954.
  Horwood argues that the mine action sector's overall steering mechanisms are weak, especially with respect to adopting a rights-based approach to mine action (which views the presence of mines and explosive ordnance as a violation of human rights and international norms). It also advocates for more rigorous tools and analysis to target mine action interventions in areas where they will have the most impact, not just the highest economic returns.

- Kalamar, Tina. "Social Inclusion of Marginalized Communities: Mine Action in Laos".
  Journal of conventional Weapons Destruction 21, no. 2 (2017): 44–47. This article advocates adopting an intersectional approach to consider inclusion and evaluation of the benefits of mine action in a diverse environment such as the Lao PDR, in which vulnerabilities and inequalities can be present along gender, age, income, and ethnic minority lines.

- Land Rights and Mine Action in Myanmar. Displacement Solutions. 2014.
  This study argues that in situations where land rights and systems of land tenure are fluid, especially in areas with ongoing conflicts, mine action interventions can actually be harmful and exacerbate extant inequalities and power dynamics.

- Millard, Ananda S., and Kristian Berg Harpviken. Reassessing the Impact of Humanitarian Mine Action. Illustrations from Mozambique. PRIO Report 1 (2000).
  This report emphasises the need for humanitarian mine action organisations to conduct broad socio-economic impact assessments of their work and includes three case studies of communities hosting demining operations in Mozambique.

- Neuma Grobbelaar (ed.). Mine Action in Southern Africa: Instrument of Development?, Johannesburg: SAIIA, 2003.
  This book discusses strategies for integrating mine action into the national development frameworks of countries contaminated by landmines and includes recommendations for mine-afflicted countries to maintain long-term donor support, as well as encouraging donor and host-country governments to learn from the experiences of other countries with similar roles in the mine action sector.

- Paterson, Ted, et al. "Landmines and Livelihoods in Afghanistan: Evaluating the Benefits of Mine Action". Journal of Peacebuilding and Development 8, no. 2 (2013): 73–90.
  Using a sustainable livelihoods approach, this article examines the enhanced well-being of people in communities affected by landmines following mine action interventions. The authors also examine the conclusions from the 1999 and 2001 socio-economic analyses of mine action programmes in Afghanistan. They conclude that, while the two studies found mine action interventions' overall benefits to be similar, the decomposition of the reasons for their benefits were almost diametrically opposed. One study cited the benefits primarily from agriculture and irrigation, while another ascribed benefits to clearance activity focused on grazing and transportation.

- Willett, Susan (ed.). Participatory Monitoring of Humanitarian Mine Action: Giving Voice to Citizens of Nicaragua, Mozambique, and Cambodia. UNIDIR. 2003.
  This book examines the possible role for participatory monitoring in the mine action sector and questions whether there is a significant role for participatory monitoring outside of victim assistance.

Donor studies on effectiveness

Various studies have been commissioned by relevant agencies within donor governments regarding the effectiveness of their overall mine action portfolios, several of which are included below.

- Bolton, Matthew. Foreign aid and landmine clearance: governance, politics and security in Afghanistan, Bosnia and Sudan. International Library of Postwar Reconstruction and Development 7, London: IB Tauris, 2010.
  Bolton's book compares the foreign aid and mine action strategies of the governments of Norway and the United States, through three case studies in Afghanistan, Bosnia and Sudan, finding a US preference for commercial clearance and rapid results, and a greater humanitarian impact from Norwegian-funded projects.

- de Jong, Philip, et al. Evaluation of Humanitarian Mine Action and Cluster Munition Programme. TANA Copenhagen. 2015.
  This evaluation of the Netherlands' mine action programming discusses the benefits of multi-annual funding in terms of more strategic long-term planning, increased operational and administrative efficiency, as well as increased flexibility in order to adjust programmes.

- Griffin, Robert and Robert Keeley. "Joint Evaluation of Mine Action in Cambodia for the Donor Working Group on Mine Action". CWD Repository 1154. 2004.
  This early report emphasises the need to strengthen the linkages between the mine action sector and national development plans, strengthening national leadership within the mine action sector, and better coordinating priorities and funding streams from a variety of mine action donors.

- Nedergaard, Mikkel. "Outcome Monitoring in Humanitarian Mine Action". Journal od ERW and mine action 18, no. 1 (2014).
  Nedergaard provides a case study on the Danish Demining Group's use of outcome monitoring systems, recognising that donors are now asking questions about the impact of demining activities on the lives of residents of contaminated areas, as frequently as they are asking questions about the number of square metres cleared or landmines removed.

- Nut, Annie, and Pascal Simon. 'Finishing the Job'. An Independent Review of the Mine Action Sector in Cambodia. GICHD. 2016. This sectoral review of mine action in Cambodia would be relevant to all donor governments contributing to mine action interventions in Cambodia. Key recommendations include making land release planning more efficient and focused on high priority areas, including through prioritising at lower administrative levels.

Economy and value for money

Literature surrounding the concepts of economy and 'value for money' in mine action includes concepts from both the efficiency and effectiveness realms, which should not be viewed as being mutually exclusive.

- Evans, Roly, and David Hewitson. "Key Performance Indicators and HMA: Time to Standardize?". Journal of Conventional Weapons Destruction 23, no. 2 (2019).
  This article argues that the mine action sector has not agreed on, or standardised, key performance indicators to allow for performance comparisons across operators, time periods, national contexts and programmes.

- Marsh, Dan. How Can Economists Help Clear Landmines and Unexploded Ordnance? New Zealand Agricultural and Resource Economics Society (Inc.). 2005.
  This report discusses several questions regarding the allocation of scarce demining resources, including the appropriate standards for clearance, targeting areas for clearance and selection of clearance methods. Additionally, the report discusses a cost effectiveness model (CEMOD) developed for the GICHD by the Management Research Centre at the University of Waikato in New Zealand.

- Souza Mülli, Albert, and Ted Paterson. "Priority-setting in Mine Action: Getting More Value for the Investment". Journal of ERW and mine action 16, no. 1 (2012).
  This article suggests that, even with dedicated prioritisation procedures, prioritisation of mine action tasks rarely meets country needs or community preferences. It goes on to stress that operators should have the latitude to make tactical clearance decisions in line with national strategies. Lastly, it states that the national mine action needs will change as the mine action environment matures through the mine action programme life cycle.

Technology

Literature surrounding the efficacy of research and development in the mine action sector is often geared towards longer-range solutions rather than incremental improvements in existing technologies.

- Croatian Mine Action Centre. International Symposium Mine Action Books of Papers. 2005–2022.
  This series of papers, produced following the annual International Symposium Mine Action held by the Croatian Ministry of the Interior and the Croatian Mine Action Centre, includes annual updates to mine action research.

- Furuta, Katsuhisa and Jun Ishikawa (eds.). Anti-personnel Landmine Detection for Humanitarian Demining. The Current Situation and Future Direction for Japanese Research and Development, London, UK: Springer, 2009.
  This book includes an overview of research and development of humanitarian demining technologies, specifically on research being conducted by Japanese scholars. Topics cover dual-sensor systems and ground-penetrating radar, vehicle-based sensors, and neutron quadrupole resonance and gamma-ray detection possibilities.

- Gasser, Russell. Technology for humanitarian landmine clearance. University of Warwick. 2000.
  Gasser's thesis examines the state of research and development for humanitarian demining. It also emphasises the importance of incremental improvements to pre-existing technologies, as well as overlooked areas for research, such as the use of water to soften ground in area preparation.

- Gasser, Russell. "Technology Research in Mine Action: Enough is Enough". Journal of Conventional Weapons Destruction 20, no. 1, Article 3 (2016): 6–9.
  This article is an update to Gasser's 2000 thesis, which finds that incentives for research in humanitarian demining have not changed in the intervening years, and mine action researchers are largely still confronting the same set of challenges.

- Habib, Maki (ed.). Humanitarian Demining. Innovative Solutions and the Challenges of Technology. 2008.
  This book includes a snapshot of research and development of humanitarian demining technologies which could further enhance operational efficiency and effectiveness. It includes a discussion of overall research challenges by James Trevelyan, sensors and detection techniques, and robotics and flexible mechanisms.

GICHD

Geneva International Centre for Humanitarian Demining
Maison de la paix, Tower 3
Chemin Eugène-Rigot 2C
P.O. Box 1300, 1211 Geneva 1, Switzerland

Phone | +41 22 730 93 60

Fax | +41 22 730 93 62

Email | info@gichd.org

gichd.org